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# MAGNETOM FLASH

MAGNETOM World

Summertime is
MAGNETOM World Meeting Time


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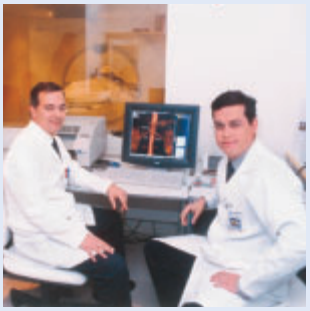
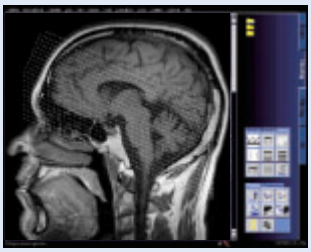
# Content

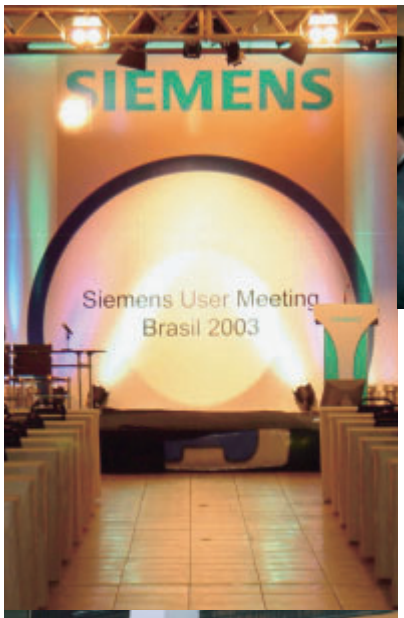






Editorial

# Summertime is MAGNETOM World Meeting Time




Our Editorial Team decision had been to include a report on one or two MAGNETOM World meetings in each Flash magazine. So, as we were planning this latest issue of Flash, we thought that MAGNETOM World Summit and one other meeting would be covered in detail. Then my old friend Gustavo Gonzalves Ribeiro called from Brazil: "Nejat", he said excitedly, "you can't believe how enthusiastic our customers were about the MAGNETOM World at their meeting in Mercosur. They say they had never seen anything like this before, for the quality of the scientific contributions and the fun". He sent me the photos and a report of the meeting. He was right. I was even worried that we would have difficulty matching that level of organization with our global MAGNETOM World Summit.

The CT/MR Users' seminar in the US is a unique tradition and the envy of all other medical imaging companies and exotic New Orleans was the chosen location for this year's meeting.

Cardiac MR is maybe the most prominent aspect of Siemens MR. We are so far ahead of the field that there is scarcely any competition. Proof of this are our CMR ambassadors – MAGNETOM cardiac MR users and leaders in the scientific community in their specific cardiac imaging areas. This year, in addition to our Miami meeting of CMR Ambassadors, we also held another MAGNETOM World meeting for cardiac MR users in Asia.

The MAGNETOM World summit in Miami was an amazing event. Not even Hurricane Lisa could disrupt the wonderful organization of an gathering that brought together people from the four corners of the world. I would like to thank again Raya Dubner from US organization and team colleague Heike Schindler for the meticulous and imaginative organization of even the smallest details of this meeting.

Do not think that we always search for sun, sea and sand when we plan our MAGNETOM World meetings. Stimulating meetings took place this summer in the cool and refined countries of Sweden and Norway, where more than 200 people gathered to exchange information and learn about latest developments.

The MAGNETOM World meeting in Mumbai, India, was also an opportunity to provide WIP sequences to our customers and get valuable feedback for optimizing our new sequences.

This is what our MAGNETOM World is all about: communication. We have the opportunity to get feedback from a worldwide community which can only help to get our products ever closer to perfection.

On the theme of perfection, we have a new MAGNETOM family member which is probably about to revolutionize the MR world: the MAGNETOM Avanto, which employs the state-of-the-art technology we have named as Tim (Total Imaging Matrix). Tim is the first seamless, whole body surface coil design that combines 76 seamlessly integrated coil elements with up to 32 RF Channels, opening the door to the most advanced clinical applications available today.

With reports on 6 meetings, Tim, Avanto, iPAT and much more, Flash is an essential source of information and a great read.

Enjoy this issue of Flash.

*A. Nejat Bengi, M.D.*
*Editor in Chief*

*We thank Harald Werner, Antje Hellwich, Lawrence Tallentire and Iman Staab for their editorial help.*

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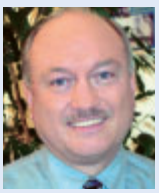

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# iPAT Applications in Clinical Routine and Beyond: Imaging from Head to Toe

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## Introduction

With the release of *syngo* MR 2002B, an important new feature has become available for routine examination: integrated Parallel Acquisition Techniques (iPAT). The general idea behind iPAT is to acquire image data simultaneously by two or more receiver coils with different spatial sensitivities. Initially, this technique was motivated by the wish to accelerate image acquisition without reducing the spatial resolution of the image. However, it turned out that iPAT provides several other advantages in various MR applications.

## Technical background

Acquisition of MR images works by subsequently acquiring phase-encoded lines in k-space. These lines of data are finally transformed into the image slice (or slab, in the case of 3D acquisitions) by a mathematical process called Fourrier transformation. An important property of data in k-space is that the density or "distance" of the lines in k-space corresponds inversely to the field of view (FOV) of the final image, whereas the data range in k-space corresponds to the spatial resolution of the image. Therefore, reducing the line sampling density by a factor of 2 (by not acquiring every other line) leads to an image with half the FOV in phase-encoding direction in comparison with the original image. In this case, the acquisition time is also reduced by a factor of 2 as is well known from using rectangular FOVs. iPAT methods use exactly this effect to accelerate image acquisition, but without decreasing the FOV due to a special iPAT image reconstruction. Using the complementary data from the different receiver coils, the "missing" lines in k-space can be calculated during image reconstruction.

There are two groups of iPAT algorithms: algorithms that explicitly calculate missing k-space lines before Fourier transforming the data, and algorithms that first reconstruct images with reduced FOV for all receiver coil elements and then merge these different images into one with full FOV. *syngo* MR 2002B provides both types of algorithms. GeneRalized Auto-calibrating Partially Parallel Acquisition (GRAPPA) is an algorithm of the first type [1] and is based on another well-known algorithm of the same class called SiMultaneous Acquisition of Spatial Harmonics (SMASH) [2]. The best-known algorithm of the second type has been called SENSitivity-Encoded (SENSE) MRI [3] and a modified SENSE algorithm called mSENSE is available under *syngo* MR 2002B. It depends on the specific application, such as the anatomical region and pulse sequence, as to which of these two iPAT algorithms will yield better image quality.

Both GRAPPA and mSENSE algorithms require some additional information about the spatial coil sensitivities, i.e. which part of the FOV is covered by each coil element. This information can be acquired as a separate extra scan with low resolution or, typical for the GRAPPA and mSENSE algorithm, by additionally acquiring some of the missing data lines in the center of k-space (so-called reference lines) integrated into the acquisition.

Generally, the signal-to-noise ratio (SNR) in iPAT images is decreased compared to acquisitions with the full k-space data. This is the same effect as in conventional imaging with rectangular FOV: acquiring fewer lines in k-space decreases the SNR of the image. Additionally, iPAT images suffer an SNR loss due to the special reconstruction scheme: this effect depends on the efficacy of the

geometry of coil distribution and is described by the so-called "geometry factor" *g* [3].

## Advantages and disadvantages of iPAT

The obvious advantage of iPAT is the acceleration of imaging due to the reduced number of phase-encoding lines to be acquired. With an acceleration factor (or PAT factor) of 2, i.e. acquisition of only every second line in k-space, the imaging time is reduced by close to 50 % depending on the number of reference lines. This can be used to decrease the overall examination time and thus improve the patient throughput and examination efficacy. Alternatively, the spatial image resolution can be improved in an iPAT scan compared to a conventional scan of the same duration. Both shorter scan times and higher resolution are especially important in breath-hold imaging: either breath-hold times can be shortened or the spatial resolution can be improved without prolonging the breath-hold time.

Another important iPAT application is dynamic imaging, such as measurements of perfusion or cardiac function, because image acceleration allows for a higher temporal resolution. However, as mentioned above, the resulting SNR will be decreased compared to non-iPAT acquisitions, so iPAT is especially useful for high-SNR applications like contrast-enhanced angiography.

Using iPAT to acquire more averages in the same total scan time can improve image quality, particularly in anatomical areas that are prone to motion artifacts. iPAT imaging is less sensitive to motion, because every single acquisition is shorter than in a conventional sequence. By averaging image data, the iPAT-related SNR loss is almost compensated and remaining motion artifacts are further reduced.

Single-shot pulse sequences, like echo-planar imaging (EPI) or half-Fourier acquired single-shot turbo spin echo (HASTE), often suffer from image artifacts due to their long echo trains. EPI is especially sensitive to susceptibility artifacts, whereas HASTE images often appear blurred due to the T2-related signal decay during the readout of the echo train. Both problems can be reduced by applying iPAT to shorten the length of the echo train without loss of spatial resolution. In contrast to other pulse sequences, single-shot methods can even gain SNR due to iPAT because late echoes with relatively low signal intensity that are acquired in conventional sequences are not contained in the shortened iPAT echo train.

In conclusion, iPAT can be advantageous in very different applications with very different ways of using iPAT. This is demonstrated in the following sections with examples ranging from clinical routine imaging to advanced study protocols. Imaging in all presented applications is performed on a 1.5 T MAGNETOM Sonata Maestro Class system. Standard sequences are used in most cases; however, some applications require sequences from special "work in progress" (WIP) packages by Siemens Medical Solutions*.

## Diffusion tensor imaging

Diffusion tensor imaging (DTI) is an advanced MR imaging technique for measuring the strength, anisotropy, and direction of water diffusion in tissue. The term "water diffusion" refers to the property of all water molecules to move stochastically due to their thermal energy (Brownian motion). The extent of this motion is restricted by tissue properties, particularly by the cellular microstructure and the spatial orientation of cells. Especially in fiber structures like muscle tissue or the cerebral white matter, molecular motion is restricted by cell membranes or myelin sheaths, and molecules move preferably parallel to the fiber direction whereas diffusion orthogonal to the fiber direction is decreased. Thus, the resulting water diffusion is anisotropic. Information about the diffusion strength (apparent diffusion coefficient, ADC), diffusion anisotropy, and diffusion direction are contained in the so-called diffusion tensor, a mathematical object (symmetric 3x3 matrix) consisting of 6 independent numbers.

The most common pulse sequences to measure the diffusion tensor are diffusion-weighted EPI sequences with diffusion gradients applied in at least six different directions [4, 5]. Single-shot EPI sequences have the advantage that imaging is fast (about 100 ms/image) and thus very insensitive to motion. However, EPI sequences are very prone to susceptibility artifacts manifesting as distortions in the frontal brain and the cranial base. This disadvantage can be overcome by using iPAT sequences to shorten the length of the EPI gradient echo train. Hence, we use a spin echo EPI diffusion sequence with GRAPPA reconstruction, an acceleration factor of 2, and 24 reference lines for DTI examinations. A dedicated iPAT head coil consisting of 8 surface coil elements (Fig. 1) provides the required number of receiver channels.

Acquisition with the 8-channel head coil results in images with an improved SNR compared to the standard quadrature head coil (Fig. 2).

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

This can be explained by the smaller diameter of the 8-channel head coil (24 cm vs. 26 cm) and the reduced coil size in cranio-caudal direction. Images were acquired with a 128x128 matrix in 36 slices, 230x230 mm² FOV, phase-encoding in anterior-posterior direction, a slice thickness of 3.6 mm, 10 averages, and an iPAT factor of 2 (24 reference lines); the echo time was 71 ms and the repeat time 6000 ms. DTI with iPAT displays less distortion artifacts than DTI with conventional EPI sequences (Fig. 3). Evaluating the diffusion-weighted images, parameter maps with the mean ADC, the diffusion anisotropy, and the main direction of diffusion can be calculated (Fig. 4). Although an N/2 artifact in phase-encoding direction (anterior-posterior) is visible in some of the original EPI images, this artifact seems not to influence the calculated parameter maps. An additional advantage of iPAT imaging is the reduced duration of the readout that allows for the acquisition of an increased number of slices within the given repetition time (TR) compared to conventional sequences, e.g., 38 slices without iPAT vs. 50 slices with iPAT given a TR of 6000 ms.

## Larynx imaging

Magnetic resonance imaging of the larynx is difficult due to tissue motion caused by swallowing and respiration [6]. Generally, MR pulse sequences with long acquisition times are more sensitive to motion than fast imaging sequences or even single-shot sequences. Therefore, MRI of the larynx at conventional speed often leads to images with excessive motion artifacts.

Since moving organs like the larynx can be more clearly visualized by reducing the image acquisition time,

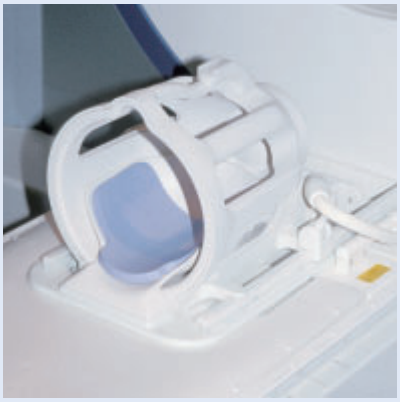

**Figure 1** *8-channel phased-array head coil for acquisition of iPAT data. 8 surface coil elements are located cylindrically around the AP axis; the inner diameter of the coil is 24 cm.*

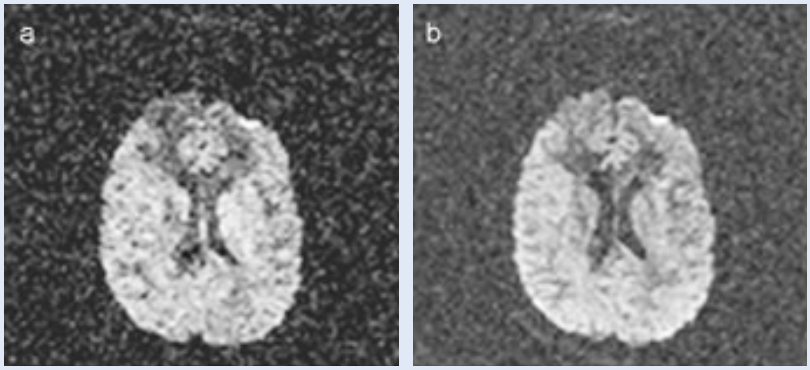


**Figure 2** *Comparison of SNR with standard head coil (a) and 8-channel head coil (b). Both images are acquired with identical sequence parameters (diffusion-weighted EPI sequence, b = 1000 s/mm², no averaging) and without iPAT.*

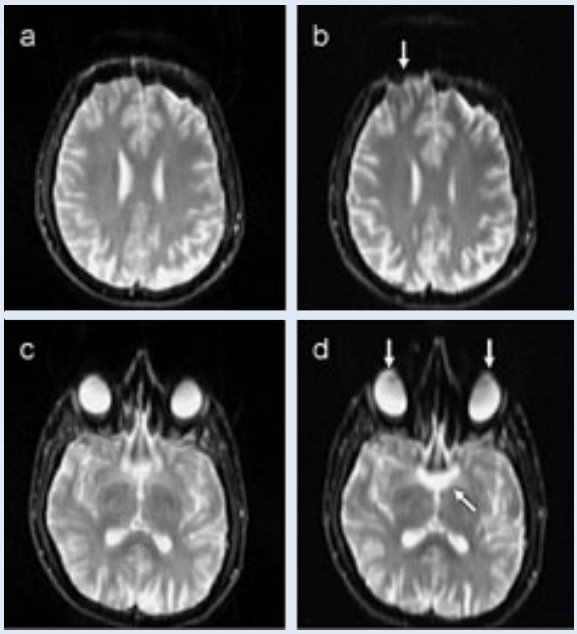


**Figure 3** *Comparison of spin echo EPI images in two slices with (a, c) and without (b, d) iPAT (GRAPPA algorithm). Some obvious susceptibility artifacts are marked with arrows in (b) and (d).*

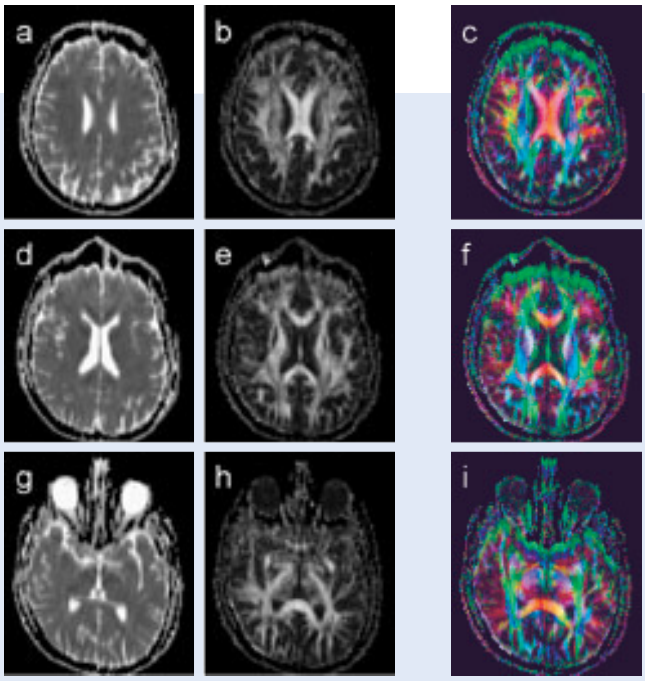


**Figure 4** *Examples of DTI evaluation from diffusion-weighted iPAT images: ADC map (a, d, g) with diffusion coefficients from 0 (black) to 2.5x10 $^{-3}$ mm$^2$/s (white); fractional anisotropy (b, e, h) from 0 (black) to 1 (white); color-coded main diffusion direction (c, f, i), left-right: red, anterior-posterior: green, cranio-caudal: blue. Note especially the high anisotropy and left-right diffusion direction in the corpus callosum.*

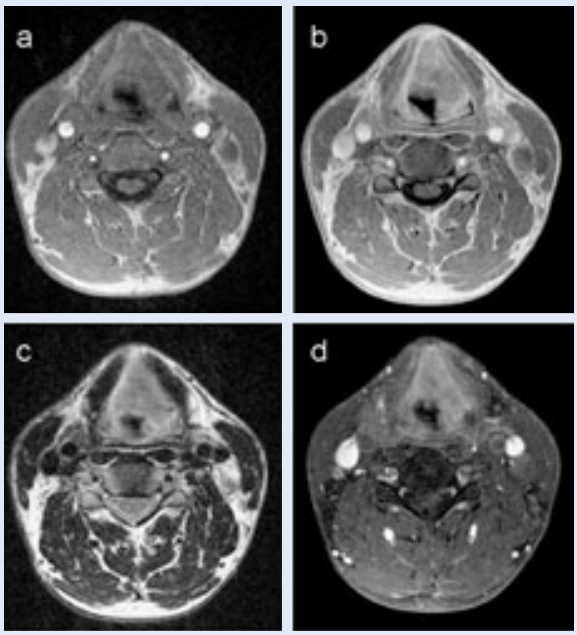


**Figure 5** *Axial MRI scan through the supraglottic larynx, all images show the same scan position. The images demonstrate a large supraglottic tumor infiltrating the preepiglottic space, the left paraglottic space and the left aryepiglottic fold.*
*(a) T1-weighted image showing muscle-isointense tumor.*
*(b) T1-weighted image demonstrating contrast-enhancement of the tumor.*
*(c) T2-weighted axial image showing slightly hyperintense tumor tissue.*
*(d) T1-weighted fatsat image demonstrating contrast enhancement of the tumor. Spinocellular carcinoma was found at surgery.*

iPAT sequences can reduce the sensitivity to motion artifacts by accelerating image acquisition while maintaining the same image resolution. Thus, we use T1-weighted and T2-weighted iPAT sequences for routine larynx imaging, e.g. in patients suffering from suspected laryngeal carcinoma. A pair of dedicated iPAT surface coil systems with 2x6 coil elements is arranged around the lower part of the head and neck of the patient. To compensate for the iPAT intrinsic SNR loss, we increase the number of acquisitions to 5 (T1-weighted gradient echo sequence with TR/TE = 176 ms/4.8 ms, 24* iPAT reference lines) and 3 (T2-weighted TSE sequence with TR/TE = 3970 ms/89 ms, echo train length 15, 45* iPAT reference lines). Both sequences have a 512x384 matrix, a FOV of 300x281.3 mm$^2$ and a slice thickness of 3.5 mm. The GRAPPA algorithm is used for iPAT reconstruction.

The acquired images show a better delineation of tumor extent and less motion artifacts than MRI using non-iPAT techniques, thus allowing accurate diagnosis of laryngeal carcinoma (Fig. 5). In our experience, MRI with iPAT using a flexible 12-element phased-array coil is suitable for reliable diagnosis when laryngeal carcinoma is suspected. Generally, in imaging moving tissue it appears preferable to acquire more averages with reduced imaging time using iPAT and thus gain images with identical resolution and comparable SNR but less motion artifacts than in conventional non-iPAT imaging.

** In each case the actual number of lines measured is half the number of reference lines mentioned in the text. This is due to the fact that every other line is already part of the iPAT scan.*

## Lung imaging

### MR screening of infiltrates

Radiological lung screening is typically performed either by conventional x-ray (CXR) examination or by high-resolution computed tomography (HR-CT) of the thorax and therefore exposes patients to a considerable amount of radiation, particularly after repeated examinations. This radiation dose could be reduced by using MRI as screening modality instead of x-ray based methods. Unfortunately, MRI of the lung is still a technical challenge because of the very low proton density of the lung tissue and the strong variation of susceptibility leading to very short T2* relaxation times. Both factors together are the reason for very low MR signal intensities from lung parenchyma and hence for a low SNR. A further difficulty in lung MRI is tissue motion because of respiration and cardiac motion.

The introduction of iPAT opened new possibilities to lung imaging with T2-weighted HASTE sequences. The main disadvantage of conventional HASTE sequences is the blurring of images caused by the long echo train and the T2-related signal decay during its readout; this effect severely limited the actual maximum image resolution [7]. By using iPAT, the echo train can be reduced to half of its original length and thus blurring artifacts are reduced. Since late echoes with low signal intensity are not acquired, SNR can even improve compared to non-iPAT sequences. Additionally, the image acquisition is accelerated such that more slices can be acquired during one breath-hold period.

To evaluate the use of iPAT HASTE sequences for lung screening, we compared HR-CT and MR images in immunosuppressed patients with symptoms of pneumonia but normal

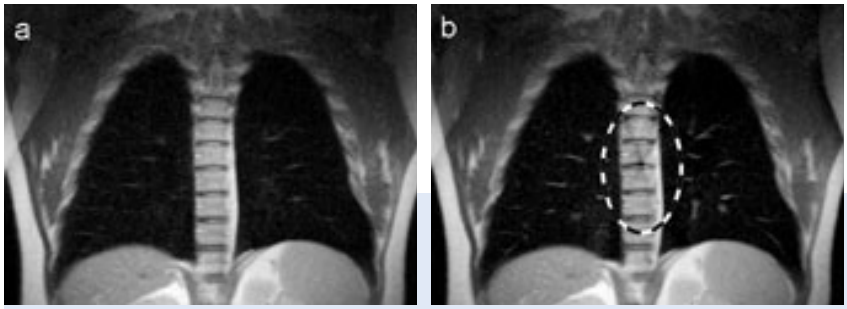


Figure 6 *iPAT HASTE images of a healthy volunteer reconstructed with GRAPPA (a) and mSENSE (b) algorithm. Note the reconstruction artifacts superimposing the spine in (b).*

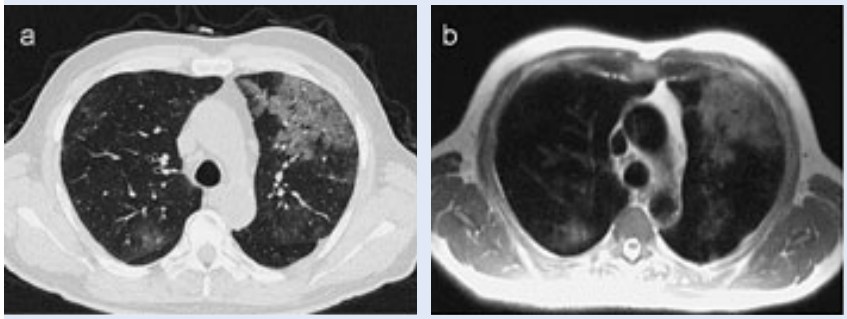


Figure 7 *Ground glass infiltrate in immunosuppressed patient. Multi-detector HR-CT (a) and iPAT HASTE MRI (b).*

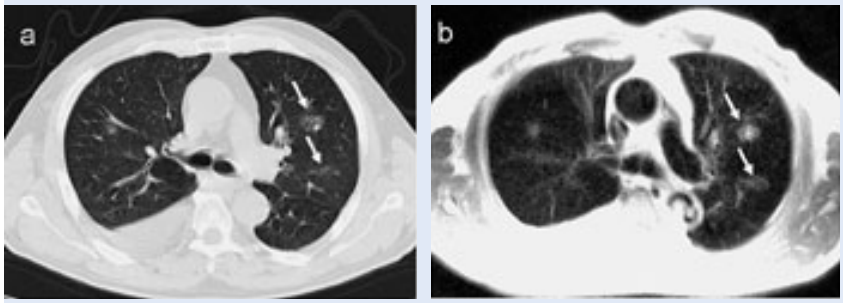


Figure 8 *Small irregular infiltrates in immunosuppressed patient. Multi-detector HR-CT (a) and iPAT HASTE MRI (b).*

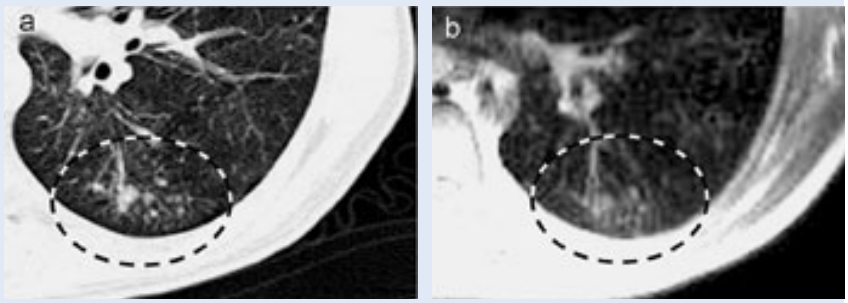


Figure 9 *Discrete atypical infiltrates in immunosuppressed patient. Multi-detector HR-CT (a) and iPAT HASTE MRI (b).*

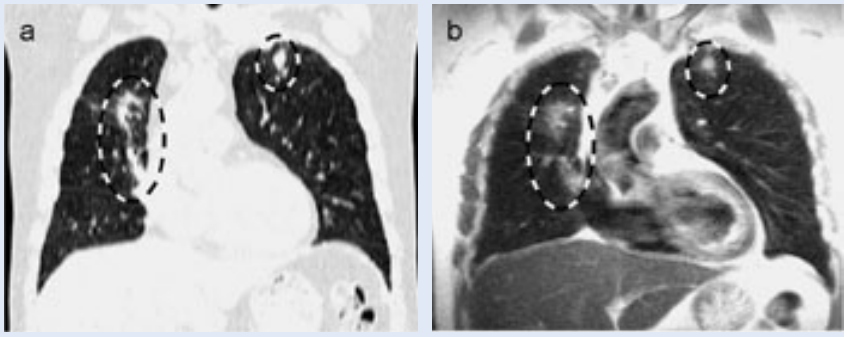


Figure 10 *Discrete atypical infiltrates in immunosuppressed patient. Multi-detector HR-CT (a) and iPAT HASTE MRI (b).*

or unspecific CXR. After comparing iPAT images reconstructed with the GRAPPA and mSENSE algorithm (Fig. 6), we decided to use the GRAPPA algorithm because of the occurrence of reconstruction artifacts in the image center of the mSENSE images. Coronal slices of the lung are acquired with a FOV of 400x400 $mm^2$ and a resolution of 320x320 pixels; axial slices with a FOV of 400x320 $mm^2$ and a 320x256 matrix. The slice thickness is 8 mm and the TE is 27 ms in both sequences. To reduce the echo train length as far as possible, a Siemens WIP* sequence was used. Examples of the findings are shown in Figs. 7-10.

We found that lung MRI with iPAT HASTE sequences is nearly as good as HR-CT for the detection of pulmonary infiltrates with only few false-negative and false-positive cases such that MRI can be recommended especially as a follow-up tool after initial HR-CT diagnosis.

### MR angiography and perfusion imaging

Contrast-enhanced vascular lung MRI requires a good spatial resolution and – especially in the case of perfusion imaging – also a good temporal resolution. Both are limited by the breath-hold duration for the patient rather than by SNR considerations due to the high-contrast situation in contrast-enhanced MRI. Experiences on MR perfusion imaging of the lung are still limited and various approaches like conventional FLASH and HASTE sequences or flow-sensitive inversion recovery techniques are used [8-10]. However, using iPAT techniques, both temporal and spatial resolution can be significantly

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

increased compared with conventional imaging.

We therefore added iPAT FLASH sequences to our protocol for 3D contrast-enhanced MR angiography (MRA) and MR perfusion imaging of patients with primary and secondary pulmonary arterial hypertension. Using GRAPPA with the optimized 12-element iPAT coil, a temporal resolution of 1.2 seconds per phase is possible for dynamic perfusion imaging, acquiring 25 dynamic phases in 30 seconds; the image resolution is 1.5x3.0x4.0 $mm^3$ acquired with a 256x128 matrix in 24 slices. High resolution angiograms can be acquired with a 512 matrix (0.8x1.0x1.6 $mm^3$ voxel size) in 20 seconds breath-hold time. For both dynamic perfusion and high-resolution angiography, an iPAT acceleration factor of 2 is used with 24 reference lines*.

Image examples of these sequences are shown in Figs. 11 and 12. Using the parallel acquisition technique, excellent visualization of subsegmental vessels is possible in the angiographic images. Time-resolved perfusion imaging allows a reliable detection of small segmental and subsegmental perfusion defects. Using non-iPAT methods, visualization of perfusion defects and intravascular thrombi is generally possible as well, although with lower temporal and spatial resolution than using iPAT methods. In conclusion, we could substantially improve the temporal resolution as well as the spatial resolution by using iPAT.

## Functional cardiac imaging

### Global and regional cardiac function

Cardiac magnetic resonance imaging has been extensively used in the assessment of global and regional myocardial function. There is no doubt that MRI represents the current standard of reference. Although dataset acquisition can be performed in virtually any plane, the calculation of functional parameters is most commonly based on a stack of slices in double oblique short-axis orientation. To allow for high spatial as well as high temporal resolution, the current sequence techniques acquire a single-slice cine data set each breath-hold. Although innovations of recent years allowed for a speed up of techniques, a completion of a standardized functional study still takes about 10-15 minutes including patient recovery periods. Real-time imaging techniques using steady-state free precession (SSFP) sequences such as TrueFISP, allow for a major speed up in data acquisition due to the completion of a short-axis dataset within a single breath-hold [11, 12]. However, this comes along with a restriction in spatial and temporal resolution. And in terms of volumetric accuracy, temporal resolution is far more crucial than spatial resolution as recently shown by Miller and co-workers [13]. The current recommendation for functional cardiac imaging requests a temporal resolution of 50 ms or even better.

iPAT allows this criterion to be met when implemented in conjunction with real-time TrueFISP. Compared to previous studies performed by Barkhausen and Lee [11, 12], the temporal resolution that can be achieved is in the order of 45-50 ms. And as most recently shown, this improvement in temporal resolution now leads to an accuracy of results comparable to that of segmented TrueFISP [14] (Figs. 13-16); the iPAT images are acquired with an acceleration factor of 2 and 12 reference lines. Accordingly, iPAT not only allows for dramatic time savings in cardiac function analysis without

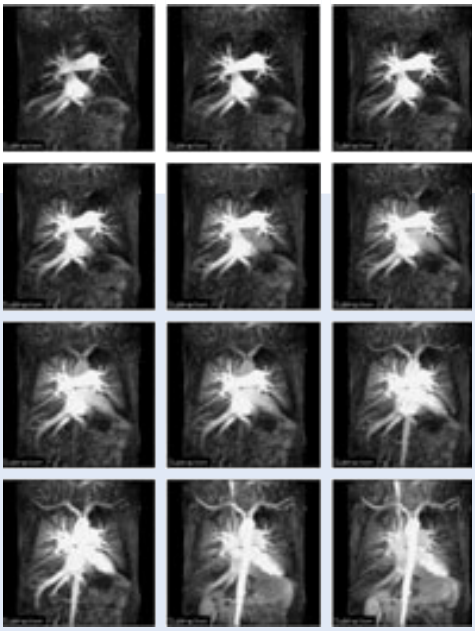

**Figure 11** *Dynamic pulmonary perfusion imaging using iPAT to acquire a slab of 24 images each 1.2 seconds. Perfusion defects are shown in the left upper lobe and right lower lobe.*

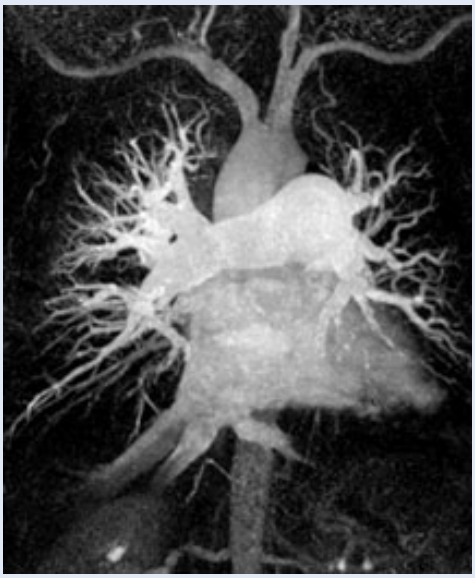

**Figure 12** *Example of an iPAT high-resolution pulmonary MR angiography of the same patient as in Fig. 11. A significant reduction of arterial enhancement can be demonstrated in the left upper lobe and right lower lobe due to central thromboembolic occlusions.*

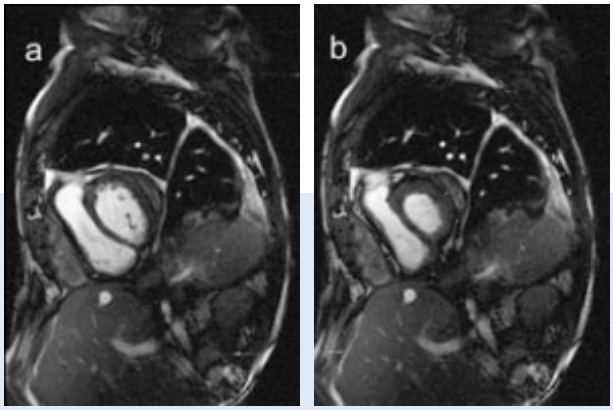


**Figure 13** *Short axis view of a male patient with impaired right ventricular function due to pericardial disease. Images acquired with a segmented TrueFISP technique showing diastole (a) and systole (b).*

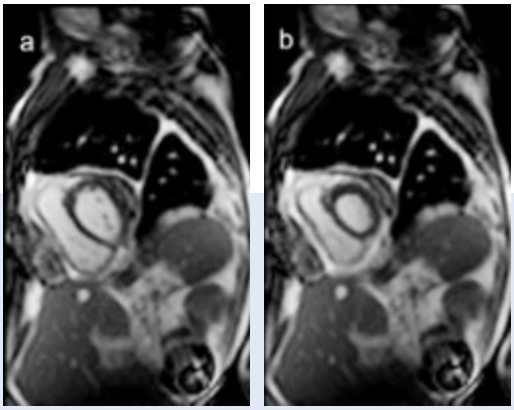


**Figure 14** *A single slice of the multi-slice iPAT real-time cine data set at exactly the same slice position as in Fig. 13. Comparable time points in (a) diastole and (b) systole.*

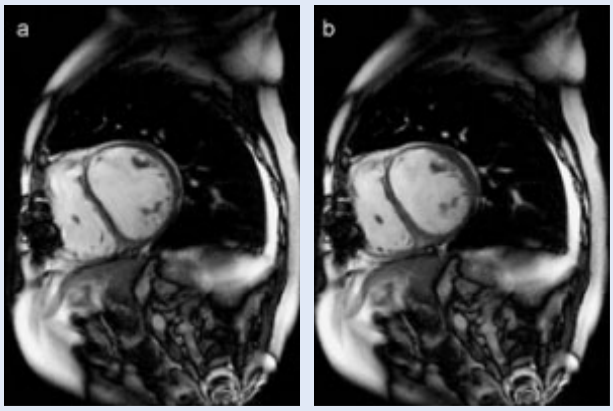


**Figure 15** *Patient after myocardial infarction with ischemic dilatating cardiomyopathy. Diastolic (a) and systolic (b) images acquired with segmented TrueFISP show almost no change in ventricular shape (ejection fraction < 25 %).*

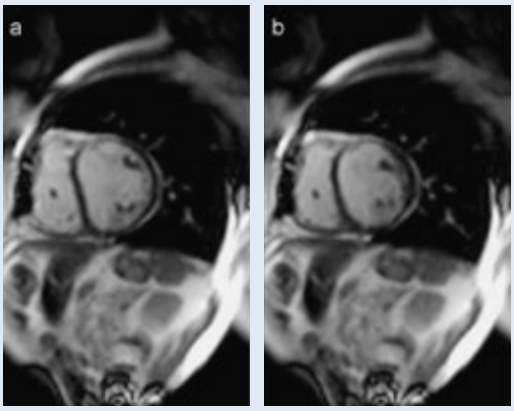


**Figure 16** *Comparison with Fig. 15 at identical slice position. iPAT real-time TrueFISP shows the same marked thinning of the anterior wall without change within diastole (a) and systole (b).*

** In each case the actual number of lines measured is half the number of reference lines mentioned in the text. This is due to the fact that every other line is already part of the iPAT scan.*

losing accuracy of volumetric results, but even allows for a multiplanar data acquisition within a single breath-hold.

Based on experiences and comparisons, the GRAPPA reconstruction shows a more robust image quality in cardiac MRI than mSENSE [1]. Due to the higher sensitivity of SENSE-related methods to folding artifacts, these techniques seem to be less useful in cardiac imaging because of the necessary larger FOV that leads either to an additional loss of spatial resolution or to loss of acquisition time when more phase-encoding lines are acquired. Apart from the use of iPAT with real-time techniques, it also allows for a further improvement of spatial or temporal resolution in segmented single-slice acquisitions compared to standard techniques (Fig. 17). In general, when using cine TrueFISP techniques, the loss in SNR due to iPAT is almost negligible.

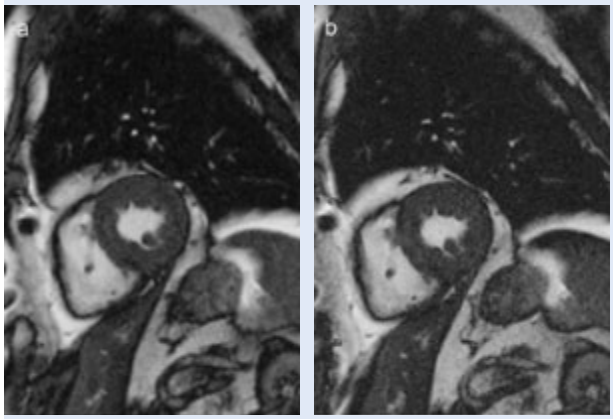


**Figure 17** *Combination of segmented cine TrueFISP with iPAT. In comparison to standard techniques (a; pixel size 1.5x1.5 mm²), the use of iPAT allows for a marked increase of spatial resolution (b; pixel size 1x1 mm²).*

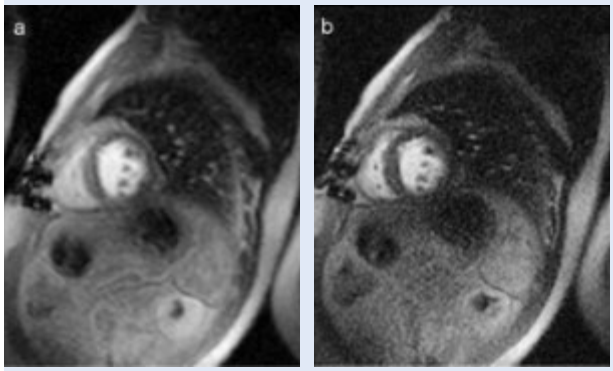


**Figure 18** *Images of MR perfusion data sets using a saturation recovery TurboFLASH technique. Comparison of a non-iPAT TurboFLASH technique (a) with an iPAT (GRAPPA) TurboFLASH technique (b). There is considerable more noise within the iPAT image which hampers depiction of perfusion abnormalities based on the low SNR.*

### Myocardial perfusion imaging*

Myocardial perfusion imaging is a promising and rapidly increasing field in cardiac MRI. The rapid development of scanner hardware allows also for an improvement in sequence technologies which has been of a major benefit in techniques that require an ultra-fast data acquisition such as myocardial perfusion imaging. MR perfusion imaging has intrinsic benefits compared to routinely used techniques of nuclear medicine such as single photon emission computed tomography (SPECT) imaging or even positron emission tomography (PET) which represents the current gold standard in clinical perfusion imaging. Apart from the higher spatial resolution and lack of radiation exposure, myocardial MR perfusion imaging has no attenuation problem related to anatomical limitations.

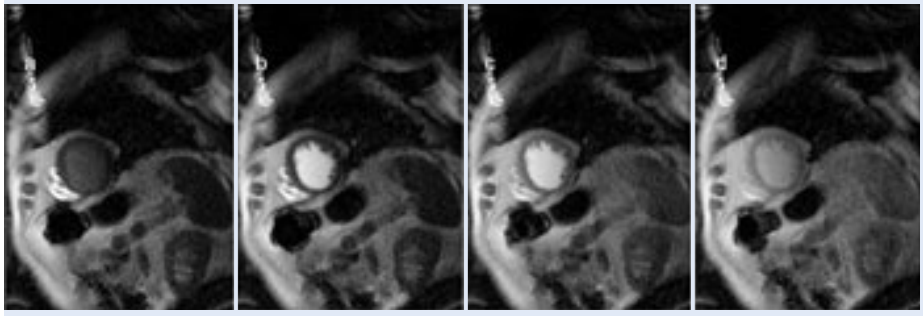

**Figure 19** *Saturation recovery TrueFISP perfusion images combined with iPAT (GRAPPA) and a high in-plane resolution of 2.1x2.1 mm². In contrast to saturation recovery TurboFLASH, the spatial resolution is still high enough to follow signal dynamics.*

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

With the use of magnetization-prepared TurboFLASH techniques, however, such as saturation recovery TurboFLASH, the SNR has reached a limit (Fig. 18). Therefore a combination with iPAT techniques seems to be of less benefit, as a further loss in SNR is produced. Newly developed techniques for myocardial perfusion imaging based on SSFP techniques are currently under investigation [15]. In comparison with TurboFLASH techniques, these sequences (available as Siemens WIP package) show a considerable higher intrinsic SNR, therefore allowing for a minimal to moderate loss of SNR when combined with iPAT (Fig. 19).

## Liver imaging

MR liver imaging is most severely restricted by respiratory movement. Therefore, image quality was considerably improved with the introduction of T2-weighted turbo spin echo (TSE) and single-shot sequences. With these techniques, breath-hold examinations of the liver became possible, which most authors consider superior to conventional spin echo sequences [16-18]. Generally, a maximum breath-hold time of about 20 seconds, tolerable even for patients in bad health condition, is a limiting parameter for all sequences used for liver imaging.

Respiratory-triggered T2-weighted sequences have been studied as an alternative to the breath-hold strategy with contradictory results [16, 19, 20]. An advantage of respiratory-triggered sequences is the ability to perform high-resolution examinations with 5 mm slice thickness which has not been possible with breath-hold sequences due to the limited breath-hold time. An attempt to overcome this limitation of breath-hold imaging by examinations with multiple breath-holds such that the liver is examined in several stacks of slices, may result in parts of the liver being missed if the patient does not meet the same position of the diaphragm in all stacks [19].

The development of iPAT allows for a substantial reduction of acquisition time, and thus breath-hold sequences with improved spatial resolution can be used. 2D navigator-based techniques, as the Prospective Acquisition Correction (PACE) technique, known from cardiac imaging, can adapt the stacks of slices according to the respiratory position by registering the diaphragm position, so that the whole liver can be covered even if the patient does not hold his breath at the same position [21].

We compared four high-resolution T2-weighted sequences with 5 mm slice thickness and a 320x240-256 matrix for routine liver imaging: a breath-hold TSE sequence with and without iPAT and PACE (echo train length: 27, TR = 2120 ms, TE = 87 ms, 4 breath-hold cycles, iPAT factor 2, 24 reference lines*), and a respiratory-triggered TSE sequence with and without iPAT (echo train length: 25, min. TR = 2680 ms, TE = 117 ms, iPAT factor 2, 24 reference lines). All images were acquired with a 12-element surface coil system optimized for iPAT applications. A respiration belt was used for triggering. The aim was to demonstrate the feasibility of iPAT and PACE for T2-weighted liver imaging and to evaluate image quality of the different sequences.

Image examples of all sequences are shown in Figs. 20 and 21. In general, imaging with iPAT reduced the acquisition time by almost 50% without visible SNR loss. Comparing breath-hold and respiratory-triggered techniques, the latter turned out to be more robust in patients whereas no difference in image quality was observed in volunteers. An explanation for this result is that patients have more difficulty with the breath-hold period of up to 20 seconds. In conclusion, iPAT liver examinations with respiratory triggering appear to be the most robust approach for clinical routine examinations.

** In each case the actual number of lines measured is half the number of reference lines mentioned in the text. This is due to the fact that every other line is already part of the iPAT scan.*

## High-resolution renal MR angiography

Three dimensional gadolinium-enhanced magnetic resonance angiography (3D-Gd-MRA) has gained high popularity as a non-invasive imaging alternative for grading of renal artery stenosis [22]. High accuracies of over 90 % have been reported by numerous researchers in the past five years [23]. Nevertheless, the technique is still notoriously known for over-grading high-grade renal artery stenoses and missing low-grade lesions, thereby limiting its overall clinical acceptance [24]. A recent Dutch multi-center trial presented less encouraging results with overall accuracies of only 85 % compared to DSA. In addition, no reliable data on grading of stenoses of the more distal main renal artery or segmental arteries exists yet [25].

One major limiting factor is spatial resolution. For standard breath-hold acquisitions with bolus administration of extracellular, non-intravascular gadolinium chelates, the maximum achievable spatial resolution represents a compromise between scan time, anatomic coverage and SNR. Current imaging protocols usually obtain images with a maximum of 1.5 $mm^3$ isotropic resolution which still represents 5 to 7 fold less than that of digital subtraction angiography

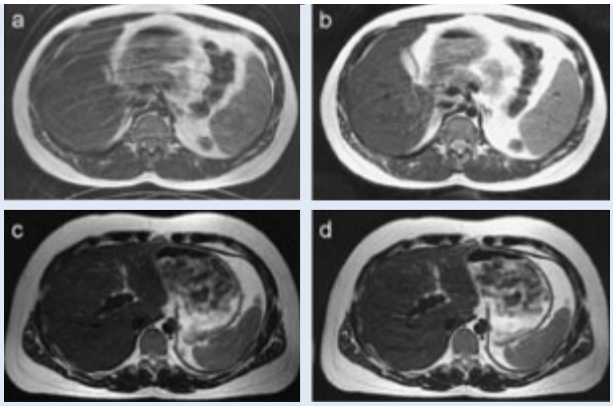


Figure 20 *Examples of T2-weighted liver images: Breath-hold sequence without iPAT (a) and with iPAT (b), respiratory triggering without iPAT (c) and with iPAT (d). Note the markedly reduced artifacts in the breath-hold sequence with iPAT (b) of this subject, who had problems holding his breath. Respiratory triggering as well compensated this problem.*

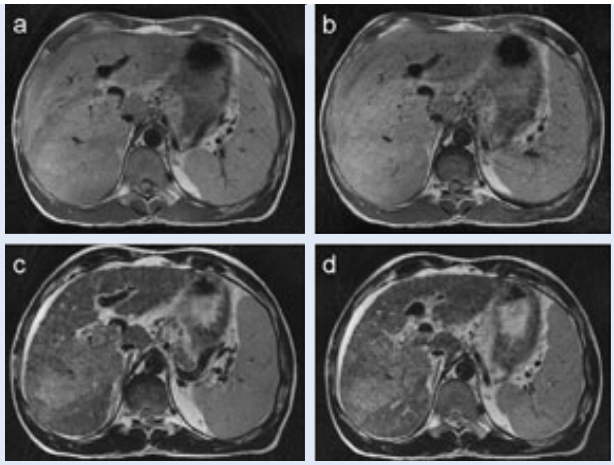


Figure 21 *Examples of T2-weighted liver images: Breath-hold sequence without iPAT (a) and with iPAT (b), respiratory triggering without iPAT (c) and with iPAT (d). Respiratory triggering shows less motion artifacts and better delineation of the diffuse HCC due to better T2 contrast.*

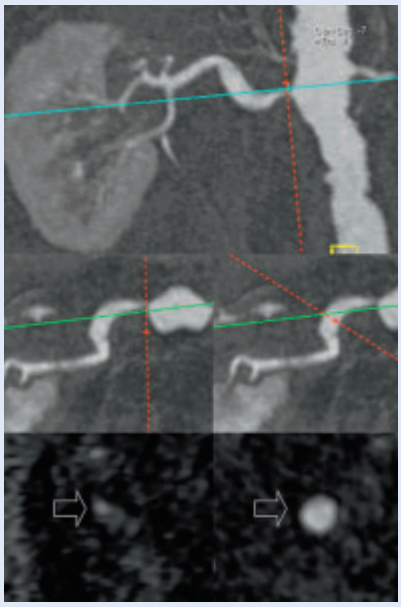

Figure 22 *Multiplanar reformats of a high-resolution 3D-Gd-MRA. In the cross-sectional reformats of the vessel (lower image series) even the area of the stenotic lumen can be clearly demonstrated due to the isotropic spatial resolution.*

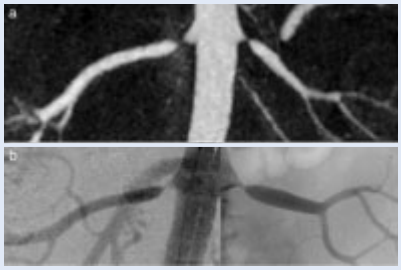

Figure 23 *Coronal MIP image of high-resolution MRA with iPAT (a) reveals excellent agreement to DSA (b). Both high-grade renal artery stenoses are seen including the residual vessel lumen. Note the absence of any major aliasing artifacts in the center of the image.*

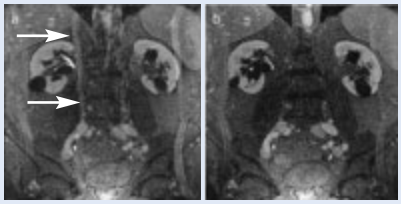

Figure 24 *Comparison of propagated aliasing artifacts in the same patient using the mSENSE (a) and GRAPPA (b) algorithm. The field of view was on purpose set to only 32 cm to enforce aliasing of the arms. In the mSENSE images severe artifacts occur in the center of the image (arrows) while these artifacts are virtually absent on the GRAPPA images.*

(DSA). In a renal artery with a diameter of 7-8 mm, an isotropic voxel size of at least 1 $mm^3$ is required for accurate depiction of a 90 % reduction in lumen diameter.

Parallel acquisition techniques allow for improvement of spatial resolution without prolonging data acquisition and are well suited for images with a high SNR such as 3D-Gd-MRA. Based on previous calculations, it is expected that voxel sizes of less than 1 $mm^3$ are substantially limited by SNR constraints [26]. Therefore, it was our aim to increase spatial resolution to maximum values within this range. The iPAT strategy was applied on an 8-channel MAGNETOM Sonata Maestro Class System in combination with a fast 3D FLASH sequence (TR = 3.79, TE = 1.3, Bandwidth = 350 Hz/pixel, flip angle = 25°). Nearly isotropic data sets with a spatial resolution of 0.8x0.8x1 $mm^3$ could be acquired within 23 seconds [27]. For signal reception the 12-element array coil system was used. An acceleration factor of 2 was used with 24 reference lines for auto-calibration of the coils. For data acquisition and reconstruction, the GRAPPA and mSENSE algorithms were compared in terms of artifacts. To improve the contrast-to-noise ratio, the one molar contrast agent gadobutrol (Gadovist®, Schering AG, Germany) was administered at a dose of 1.25 mmol/kg body weight with an injection rate of 2 ml/s.

In the iPAT images, SNR decreased by a factor of about 1.5 compared to the data without iPAT. This decrease in SNR could be visually noticed in the source images, however the intravascular signal was still acceptable. In the MIP images, the overall decrease in SNR was hardly detected.

The high-resolution renal 3D-Gd-MRA data sets were compared to selective x-ray angiography in more than 20 patients with renal artery stenosis ranging from 20 % luminal narrowing to occlusion. Image analysis of the isotropic data sets consisted of multiplanar reformats along the vessel axis to assess the degree of diameter reduction. In addition, reformats perpendicular to the vessel axis were performed to assess the degree of reduction of vessel area. Using multiplanar reformats the degree of stenosis was correctly assessed in 18 of 20 patients. In 2 cases, the degree of stenosis was overestimated. However, when reformats were performed in the isotropic data sets perpendicular to the vessel axis, all stenoses could be correctly identified compared to x-ray angiography (Figs. 22 and 23).

One limitation is the propagation of aliasing artifacts into the center of the image. These artifacts could be theoretically avoided by extending the FOV in the left-right direction so that no aliasing occurs at all. In clinical practice, however, this would mean a substantial increase in scan time, in particular in large patients. In addition, not all patients are able to put their arms over their heads. Therefore some degree of aliasing into the margins of the FOV has to be accepted. Using the GRAPPA algorithm, artifacts propagating from tissue outside the FOV into the center of the image were kept at a minimum. Only slight ring-like artifacts occurred, which did not affect the image interpretation. However, when the mSENSE technique was alternatively used, these artifacts were more severe (Fig. 24).

In conclusion, high-resolution renal 3D-Gd-MRA using iPAT allows for substantial improvement of spatial resolution, thereby increasing diagnostic accuracy compared to digital subtraction angiography. Using the GRAPPA based algorithm, artifacts propagating into the center of the FOV can be kept at a minimum.

## Whole-body imaging

Because of the recent improvements in hardware and software and the lack of ionizing radiation, magnetic resonance imaging has become a candidate for screening imaging [28]. We have developed an MR examination which combines well established components including functional cardiac imaging together with myocardial perfusion* imaging, imaging of the lung, brain, an overall view of liver, kidneys, spleen, and pancreas, as well as the arterial system.

The whole-body examination is performed in two parts. In the first part, the patient is in a head first position; the spine array, two body arrays, and a head array are used as receiver coils. In the second part, the patient is in a feet first position; the spine array, the large FOV adapter, one or two body arrays (depending on the height of the patient), and the peripheral angio array are used as receiver coils. iPAT with an acceleration factor of two is applied for most scans of the examination including real-time TrueFISP imaging of the heart (Fig. 25), high-resolution imaging of the lung (Fig. 26) as well as dynamic cardiac perfusion* MRI with TrueFISP. In addition, iPAT of 3D-Gd-MRA in combination with the large FOV adapter is performed for all studies allowing a total scan time of only 62 seconds to cover the area from the thoracic aorta down to the toes at a spatial resolution of less than 1.4x1.0x1.5 $mm^3$ (Fig. 27).

By applying the GRAPPA algorithm with its integrated auto-calibration scan, it is possible to use flexible combinations of receiver coils with a flexible choice of iPAT directions and

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

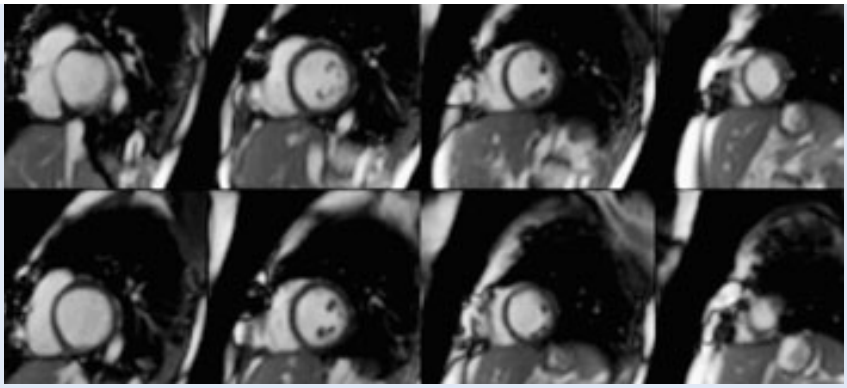

Figure 25 *Single breath-hold evaluation of global cardiac function with real-time iPAT TrueFISP.*

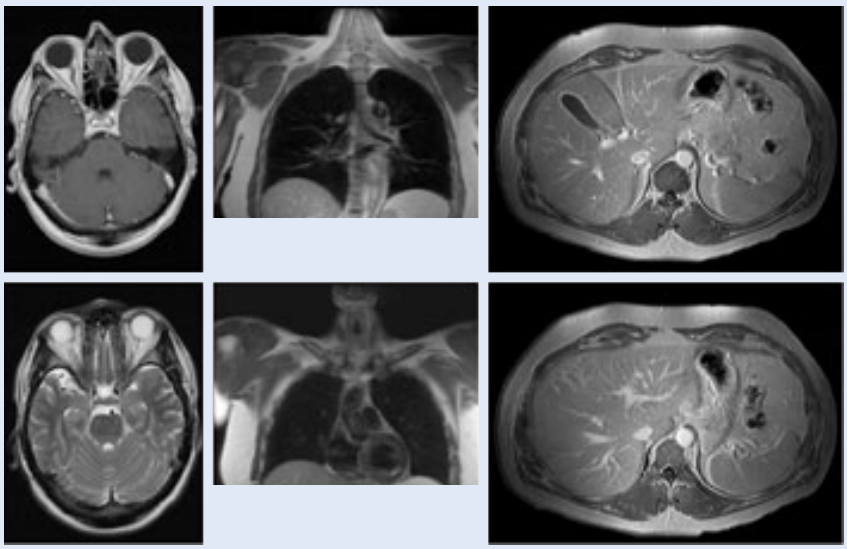

Figure 26 *Imaging of the brain, lungs, and abdomen as part of the whole-body screening examination.*

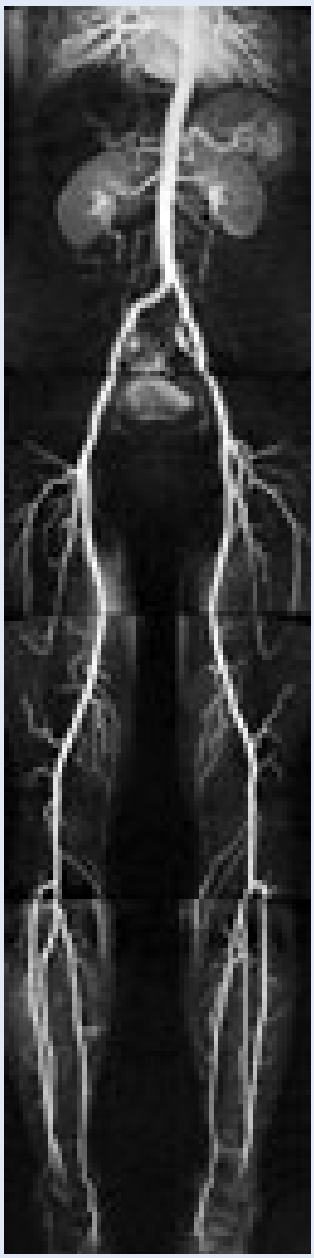

Figure 27 *Example of gadolinium-enhanced MR angiography as part of the whole-body screening examination. Note the excellent visualization of vessel segments down to the pedal arch. No stenoses are present.*

to move the patient table for different iPAT acquisitions. The advantage of iPAT in this kind of exam is the coverage of a large anatomic region and gain of time.

In the last two months twenty individuals, referred by their physician while participating in a manager healthcare program, underwent the whole-body scan in our department. All twenty individuals tolerated the MR examination well. Compared to the conventional examination techniques like ultrasound and ECG, we have established a more comprehensive exam within reasonable scan time. First results of pathologic findings (scar in lung, aortic stenosis, renal artery stenosis) show good correlation with the gold standard examinations.

## Conclusion

This overview on applications and ongoing studies in different areas of the body supports the current trend to use parallel imaging in the majority of clinical scan protocols. The general advantages of parallel imaging are now well established. This includes the possibility for higher spatial resolution for 3D-Gd-MRA with shorter breath-holds, thereby potentially improving the accuracy of this technique for grading of renal artery stenosis. The combination of time-resolved and high-resolution 3D-Gd-MRA improves the detection and differentiation of pulmonary hypertension. The use of shorter echo trains for single shot HASTE or echo planar imaging results in less image distortion and less signal decay. Initial results show benefits for EPI diffusion tensor imaging in the brain as well as detection of early infiltrates in the lung with HASTE imaging. Imaging with multiple averages in shorter acquisition times improves visualization of tumors in areas with increased motion such as the larynx. Higher temporal resolution improves the accuracy of cardiac real-time techniques using SSFP sequences to measure global cardiac function within a single breath-hold.

In addition to the general benefits of parallel imaging, the iPAT methods GRAPPA and mSENSE feature some unique advantages. Artifacts in the center of coronal images resulting from aliasing of tissue outside the FOV are substantially suppressed using the GRAPPA algorithm. The iPAT algorithms with auto-calibration integrated into the individual scan are less sensitive to patient motion than other parallel imaging techniques with a single measurement of the coil sensitivity profiles at the start of the examination. In addition, the IPA™ (Integrated Panoramic Array) allows a flexible combination of multiple receiver coil systems. Therefore, large anatomic coverage with various receiver coils and a flexible choice of the iPAT directions is possible. This is particularly helpful for whole-body imaging where multiple receiver coil systems are combined to scan the entire body with parallel imaging techniques. Scan time for a complete cardiovascular exam is substantially reduced while spatial and temporal resolution of the individual scans are preserved.

In conclusion, iPAT can be used to improve most clinical protocols for comprehensive morphologic and functional imaging. Depending on the specific application its main advantages are a decrease in imaging artifacts or an increase in speed, spatial, or temporal resolution.

## Co-workers on parallel imaging

**Roger Eibel** (pulmonary imaging)
**Wilhelm Flatz** (imaging of the larynx)
**Peter Herzog** (pulmonary imaging)
**Armin Huber** (cardiac imaging)
**Wolfgang Klinger** (MR technician)
**Harald Kramer** (whole-body imaging and screening)
**Konstantin Nikolaou** (cardiac imaging and pulmonary imaging)
**Carola Schmid** (MR technician)
**Frank Stadie** (MR technician)
**Robert Stahl** (diffusion tensor imaging)
**Anja Struwe** (MR technician)
**Bernd J. Wintersperger** (cardiac imaging)
**Christoph Zech** (abdominal imaging)

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# Motion Under Control with Prospective Acquisition Correction (PACE)

Michael Szimtenings, Ph.D.
Siemens Medical Solutions USA, Inc.

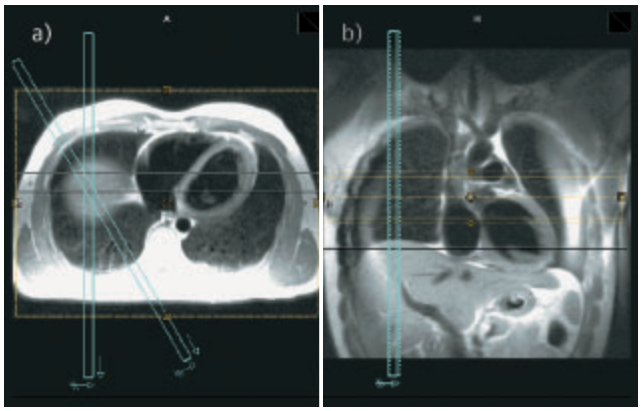


**Figure 1** *Positioning of the pencil-shaped volume across the diaphragm for 1D PACE in an axial (a) and coronal (b) plane. The cross-section of the pencil-shaped volume is defined by the intersection of the two turquoise boxes in the axial plane. The length of the pencil-shaped volume is depicted in the coronal plane (turquoise box).*

In a variety of MRI applications, motion can adversely affect image quality. Since patient motion cannot be controlled sufficiently in all cases, Siemens has developed strategies to maintain image quality despite motion. Correction of motion effects at the post-processing stage would be one approach. However, there is nothing better than acquiring good data in the first place, and strategies to account for motion during acquisition are currently offered on Siemens MR scanners. These "Inline" techniques for coping with motion are collectively termed PACE (Prospective Acquisition CorrEction). Corresponding to the spatial dimensions of the dataset used for calculating the adjustment, these techniques are termed 1D PACE, 2D PACE, and 3D PACE. The first two are used mainly to deal with breathing motion, while the third one is applied for motion adjustment in neurological studies.

## 1D PACE and 2D PACE

### Method

The fastest method of detecting motion is 1D PACE (also known as a "navigator" technique). It typically requires only 30 ms and is used primarily for minimizing the effects of breathing motion in cardiac exams. For this purpose, a single line of data from a pencil-shaped volume that crosses the diaphragm is acquired. The volume is interactively placed (Fig. 1) in such a way that the position of the diaphragm can be calculated and used for motion correction – in real time. In 2D PACE, an image is acquired by means of a low-resolution gradient echo sequence featuring a low flip angle; this ensures that magnetization is not saturated, so that dark lines in the image are avoided. The user places a small box across the diaphragm on the 2D image (Fig. 2). The change in signal intensity along the axis of the box is used to determine the position of the diaphragm. Since a 2D image provides more information than a single line, this method is very robust. The time needed to acquire an image for 2D PACE is around 100 ms. The highly reliable 2D PACE technique is unique to Siemens.

The advantages afforded by 1D and 2D PACE can be used in a variety of ways.

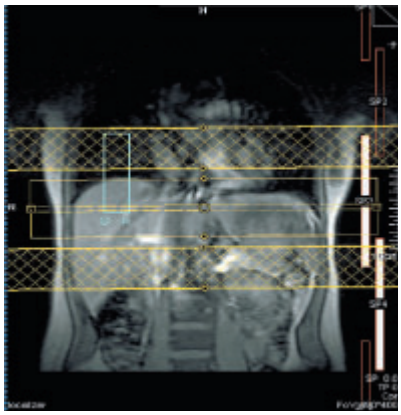

**Figure 2** *Selection of the 2D area (turquoise box) used for detection of the diaphragm position when using 2D PACE. Half the box should cover the lungs, the other half the liver.*

### Application: Multiple breath-hold examinations

For patients who can hold their breath for only a short time, the acquisition can be split up into multiple breath-holds. The information about the diaphragm position allows the operator to monitor the breathing pattern of the patient online. Furthermore, acquisition of slices during different breath-holds can be aligned in order to compensate for imperfect reproducibility of the breathhold position. In this way, gaps between slices or overlaps are avoided.

Without PACE, the operator would have to visually inspect the image-stacks and determine if there are gaps or overlaps between them – a tedious process that is highly operator-dependent. During this time the patient would have to remain in the scanner, since it might be necessary to cover gaps with additional scans. Therefore, a lack of PACE capabilities would cause unnecessary and costly prolongation of the total exam-time, which in turn would lead to decreased patient compliance and comfort.

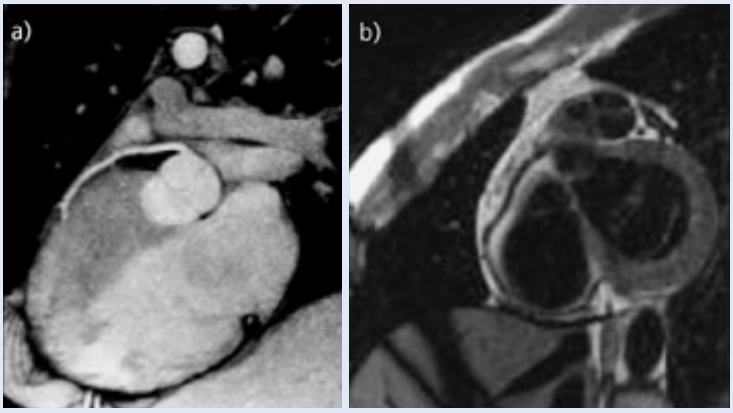


**Figure 3** *Images of coronary arteries acquired using 1D PACE. In (a) the left coronary artery is visible brightly due to the bright-blood contrast inherent to the TrueFISP sequence. In (b) the right coronary artery is displayed as a dark line, since the black-blood contrast preparation of the TSE sequence makes the blood signal disappear.*

**Application:**
**Breathe freely with PACE**

For some patients, even the shortest breath-hold duration might be too demanding; or, patients may be unable to follow breathing commands due to impairments in mental status. In such cases, PACE allows for imaging while the patient is breathing freely. During a short "learning phase", the breathing of the patient is analyzed and the central position of an "acceptance window" is calculated automatically. Next, the gated acquisition begins: slices are acquired only when the diaphragm position falls within the acceptance window. Here, the slice positions of different scans can also be aligned based on information about the position of the diaphragm. Without PACE, it would be extremely difficult (or even impossible) to perform useful MR studies in patients who cannot hold their breath.

**1D PACE or 2D PACE**

Whether 1D PACE or 2D PACE should be used depends on the application. Cardiac exams benefit from the speed of 1D PACE. In order to obtain cine-images with high frame rates, motion detection should be as fast as possible. Also, saturation in the pencil-shaped volume is not a problem, since it can be placed outside the heart. Fig. 3 shows images of coronary arteries acquired in this way. For abdominal imaging, 2D PACE is the best choice, since the scan time extension is not significant. On multi-breathhold exams, for example, breath-hold times are extended only by a tenth of a second as a result of using 2D PACE.

## 3D PACE

Functional MR imaging (fMRI) is another application where motion detection, and instantaneous adjustment of the acquisition according to this information, are crucial. Here, complete multi-slice EPI datasets of the head are acquired in rapid succession during presentation of various stimuli. In order for the statistical analysis to be successful, the datasets need to be aligned perfectly. For this purpose, each 3D dataset is compared with the previous one and the translation as well as the rotation of the head are calculated (and displayed) in real-time. The software is able to compensate for rotations and translations in all 6 degrees of freedom. The technique can therefore account, in real time, for any so-called "rigid-body motion". For acquisition of the next dataset, slice position and orientation are adjusted according to the altered position of the head.

For 3D PACE, no additional data acquisition is needed since the detection of motion is done on the actual imaging data, which is typically reacquired every 2-4 seconds. To account for potential motion effects even within this short period of time, a further retrospective correction is applied (in realtime) to the data. The interval between acquisitions can be as low as 100 ms for the hardware to be able to adjust to the movement. 3D PACE is a feature unique to Siemens scanners. Its usefulness can be seen in Fig. 4: without motion correction at all, or with retrospective correction only, the fMRI activation maps are much less meaningful (statistically significant differences are "lost" in the motion-induced "noise"). Without 3D PACE, fMRI studies such as the one shown in Fig. 5 would be much noisier and may even turn out to be entirely useless due to motion artifacts.

## Conclusion

The essential feature of Siemens' PACE technology is the prospective adjustment of an acquisition's scan parameters in order to minimize motion artifacts. With the help of 1D and 2D PACE, breathing motion can be monitored and corrected, and the variability of breath-hold positions in multiple breath-hold exams can be virtually eliminated. 1D PACE takes very little extra time, making it ideal for cardiac MR exams. 2D PACE features small flip-angles, leaving the magnetization in the volume of interest practically undisturbed. It is also a very robust technique, making free-breathing abdominal MR imaging

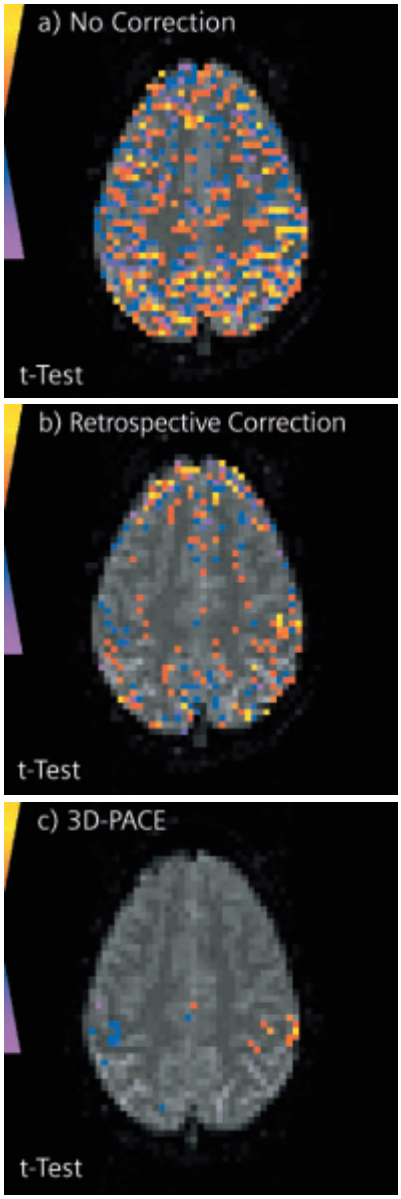


**Figure 4** *Activation maps of an fMRI study, during which the volunteer performs nodding head motions of 1.5 degrees in correlation with a stimulus. Data were acquired without motion correction at all (a), with retrospective motion correction only (b), and with 3D PACE (c). The virtual elimination of pixels falsely showing activation is clearly seen in the 3D PACE image. Only the real differences between regional activations are shown in (c).*

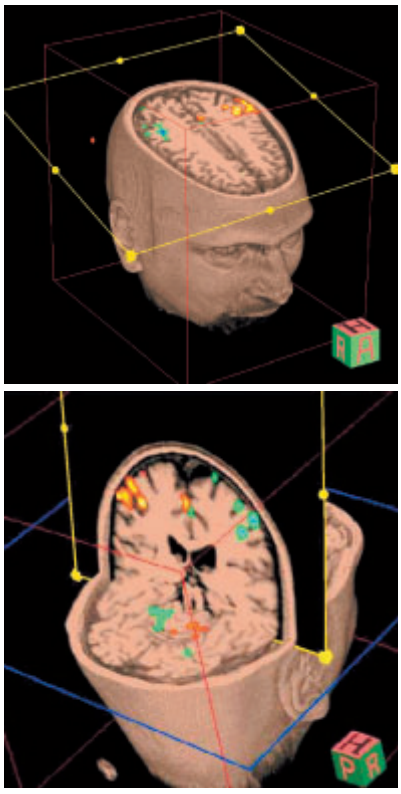

**Figure 5** *Activation of right and left primary motor cortex as detected by fMRI on a 1.5 T MAGNETOM Sonata system. The paradigm was alternating (30s/30s) left- and right-handed finger tapping. For the functional study, which took 4.0 min to acquire, 3D PACE real time motion correction was employed. An anatomical dataset was pre-acquired in 6.3 min. The use of 3D PACE improves fMRI results by ensuring more robust activation detection and better suppression of motion artifacts.*

a clinical reality. 3D PACE is capable of detecting, and correcting for, linear and rotational motion in 6 degrees of freedom and in real-time – a feature found only on Siemens MR scanners. The advanced real-time feedback capabilities of Siemens MR systems are fully exploited in the three versions of PACE to provide a more comfortable exam for patients and to produce sharper, more meaningful diagnostic images.

# MRCP with 2D PACE

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This article addresses new MRCP techniques which will be implemented within *syngo* MR 2004A* for high resolution imaging using free breathing navigator-triggered (2D PACE) 3D TSE-Restore sequences (at 1.5 T-3 T) or 3D HASTE with inversion recovery (at 0.2 T).

## Definition:

Magnetic Resonance (MR) Cholangio-Pancreatography (MRCP) is an imaging technique that noninvasively depicts biliary and pancreatic ducts. This technique shows good correlation with the Endoscopic Retrograde CholangioPancreatography (ERCP).

(Strong)T2-weighted sequences with fluid being bright allow optimal visualization of the anatomy and pathology of the biliary, and pancreatic ducts. Unlike other techniques like ERCP, MRCP also allows visualizing anatomy beyond these obstructions.

Biliary and pancreatic ductal stones are seen as filling defects, irregularities like strictures, dilatations, pancreatic cystic lesions, complex peripancratic fluid collections and islet cell tumors can be visualized.

Strong T2-weighted TSE/HASTE sequences are the best to show peripancreatic edema, fluid collections.

With pathologic changes e.g. chronic pancreatitis (an inflammatory process of the pancreas with irreversible exocrine and endocrine dysfunction, characterized by permanent replacement of normal pancreatic parenchyma with atrophy, fibrosis and calcification as well as ductal dilatation, strictures and calculi) even the dilated side branches of the pancreatic duct can be seen.

Pancreatic pseudocysts are encapsulated collections of pancreatic fluid caused by acute/chronic pancreatitis and they are well shown. MRCP is far more sensitive in detection of pseudocysts than ERCP.

A comprehensive MR imaging assessment of the pancreatobiliary tract normally includes, in addition to the strong-T2-weighted Magnetic Resonance Cholangio-Pancreatography (MRCP), a (normal) T2-weighted sequence (TSE), a T1-weighted FLASH with fat saturation and a dynamic pre/post-gadolinium T1-weighted fat suppressed FLASH sequence. The latter are not subjects dealt with in this article.

Strong-T2-weighted imaging displaying selectively non-flowing fluid in the biliary and pancreatic ducts can be done with:

- Thick slab and/or thin slices coronal/axial T2-weighted single shot TSE/HASTE
or with
- 3D TSE/HASTE techniques followed by a MIP postprocessing.

Superposition of fluid-filled bowel portions can easily be identified by subsequently performing multiangle MIP projections or by administrating negative contrast media. Nevertheless when using 3D techniques it is very important also to review the original data to avoid the loss or change of information due to postprocessing and to view also the conventional axial T1- and T2-weighted images.

Difficulties in visualizing the pancreatico-biliary system might be encountered due to either:

- motion induced artifacts (respiratory-, peristaltic-, cardiac-motion) or
- the long measurement time for obtaining high resolution.

## Option 1: Breath-hold technique

Respiratory motion artifacts can be largely eliminated to a great extent by using breath-hold techniques in combination with T1-weighted FLASH sequences with spectral fat saturation or in-/out-of-phase or with T2-weighted single shot TSE/HASTE sequences (thick slab or thin slices).

When running T2-weighted single-shot techniques due to the measurement time limited by the breath-hold duration, very high resolution is not easy to reach and the SNR is diminished in comparison with multishot-segmented TSE sequences. Furthermore, blurring due to T2 decay may occur when long echo trains are setup.

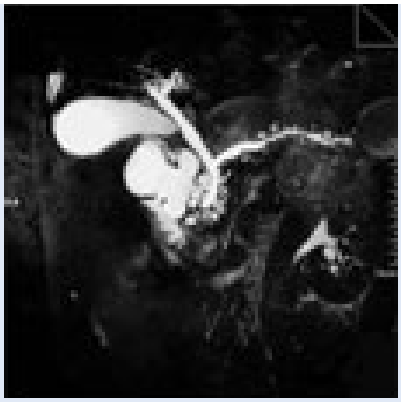
## Option 2: Free breathing technique (2D PACE MRCP)

Another technique which provides good image quality with free breathing is the 2D PACE MR Cholangiography (Available with *syngo* MR 2004A). The advantages are:

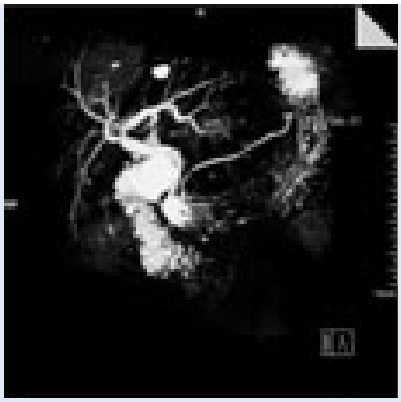
- higher spatial resolution
- better delineation of small structures, strictures and small secondary ducts as well as filling defects
- reduction of motion effects in patients who have difficulty or are unable to breath-hold.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured. The safety of imaging fetuses, infants has not been establised.*

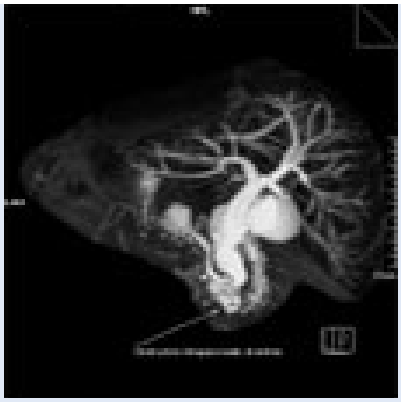
## Some image examples obtained with the new technique:



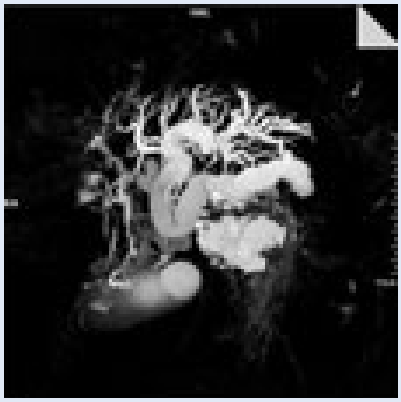
*Chronic pancreatitis – secondary branches of the pancreatic duct are clearly visible (Courtesy Prim.Univ.Doz. Dr. Gerd Reuther / Wien).*



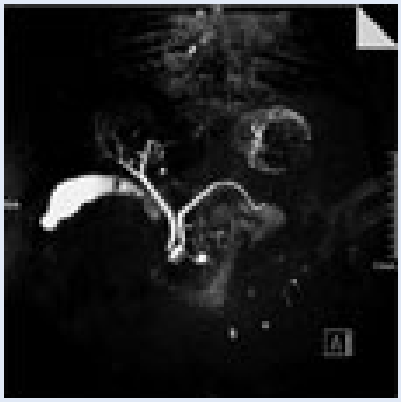
*Subcapsular liver cyst and multiple small cysts (Courtesy Dr. Markus Henschel / Bremen).*



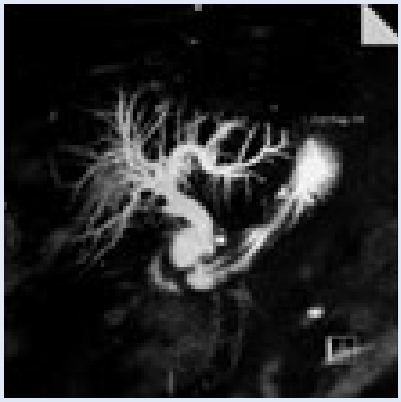
*Obstructive intrapancreatic diverticle (Courtesy Dr. Markus Henschel / Bremen).*



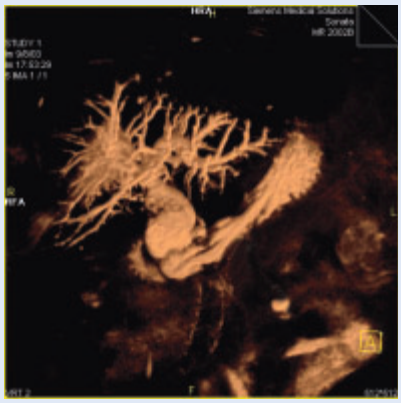
*Dillated gall bladder and bile ducts 2D PACE, free breathing (Courtesy Prof. Janisch / Erlangen).*



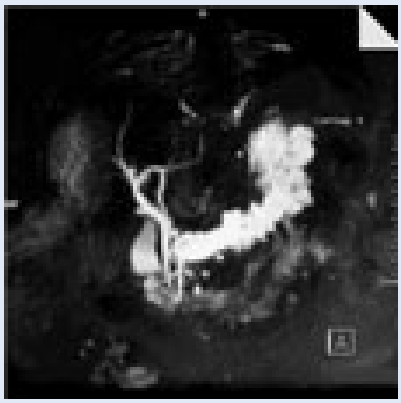
*Big gallstone in gall bladder (Courtesy Prof. Janisch / Erlangen).*



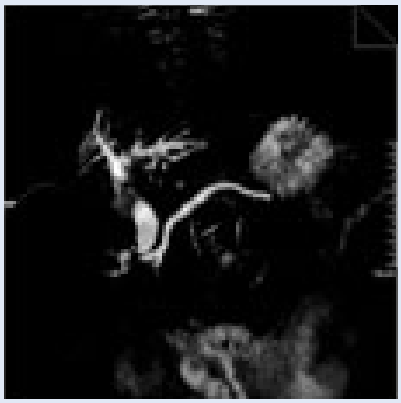
*Dilated biliary system. Chronic pancreatitis (Courtesy Prof. Janisch / Erlangen).*



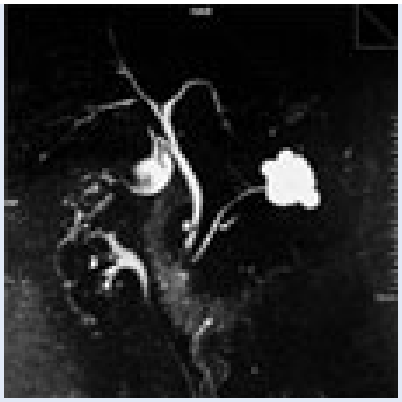
*Dilated biliary system. Chronic pancreatitis (Courtesy Prof. Janisch / Erlangen).*



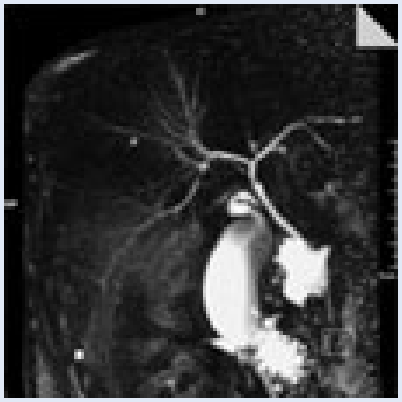
*Chronic pancreatitis (Courtesy Prof. Janisch / Erlangen).*



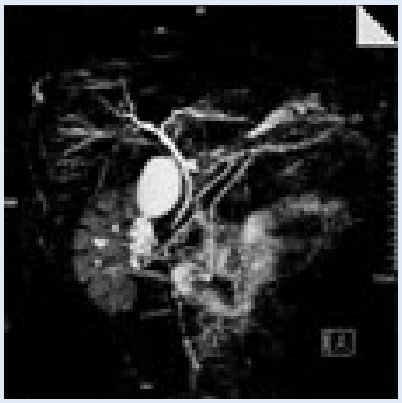
*Chronic pancreatitis – "chain of beads" appearance of the pancreatic duct (Courtesy Prof. Janisch / Erlangen).*



*Cystadenocarcinoma (Courtesy Prim.Univ.Doz. Dr. Gerd Reuther / Wien).*



*MAGNETOM Trio: volunteer with normal appearance of biliary ducts.*



*MAGNETOM Concerto: volunteer with normal appearance of biliary and pancreatic ducts.*

## How to perform 2D PACE MRCP?

Respiratory triggering reduces motion artifacts by synchronizing anatomical data acquisition with the respiratory cycle. Navigator triggering uses a navigator (i.e. MR signals) to monitor the respiratory motion. This distinguishes the new technique from the respiratory triggering technique available with the product software, which uses a respiratory belt to retrieve patient's breathing pattern. The respiratory belt is not needed for navigator triggering.

Navigator triggering is available with the TSE PACE and with the HASTE PACE sequence.

Both sequences offer the possibility to select a -90° RF pulse (the so called 'restore pulse') at the end of the echo train. This pulse flips the transverse magnetization back into longitudinal direction, which shortens the spin relaxation time.

**To plan a navigator triggered measurement, proceed as follows:**

- Select the Trigger option listed under Respiratory control on the Physio-PACE card.
- Position the navigator on the edge of the diaphragm in the coronal localizer. Navigator positioning is the same for all respiratory control modes with navigator support and is described in detail in the Siemens "Applications Guide".
- Plan the slices as normal. Set up the imaging parameters (e.g. number *n* of slices per concatenation, turbo factor) to ensure that the acquisition duration $T_{Acq}$ is between one-third and one-half of the expected average respiratory-period. The tool tip of the measurement time provides the acquisition duration. In an interleaved multi-slice measurement, the acquisition duration is *n*-times the time needed to acquire a single echo train[1]. The respiratory period is defined as the time interval from one maximum inspiration to next maximum inspiration. The respiratory period is roughly 5 seconds in healthy adults but may be substantially shorter for children or in the case of illness. The respiratory period can be measured in a brief initial measurement. Select the 'Scout mode' option in the Physio-PACE parameter card and start the acquisition. After a complete respiratory interval (i.e. end inspiration has been detected at least twice) the median respiratory period is displayed as 'Respiratory cycle' in the upper left corner of the image shown in the Online display. Remember to deselect the 'Scout mode' option prior to the actual measurement.

**Exam set-up**

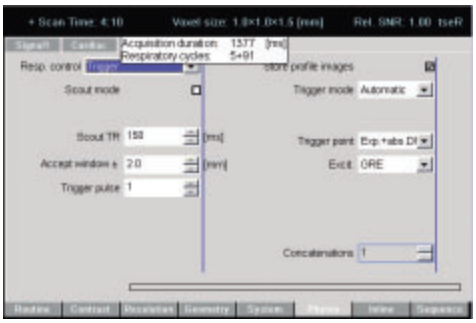



**Figure 1** *Physio-PACE parameter card.*

The predicted total scan time shown in the upper left corner of the card stack is the minimum possible scan time. The actual total scan time will be longer, depending on the actual length of the respiratory period. The second line of the scan time tool tip provides the number of required respiratory cycles in the form 5+X.

[1] *If a selective preparation pulse is used, the acquisition duration also includes the time needed to play out the preparation pulse and the time between the inversion pulse and the 90°-excitation pulse (TI-time).*

5 respiratory cycles for the learning phase of the trigger algorithm plus X respiratory cycles for the imaging phase. The actual total scan time will therefore be close to:

*Actual total scan time ≈ (5+X) ∗ Average respiratory period*

Ask the patient to breathe regularly throughout the measurement and start the acquisition.

## Principle of the navigator triggered sequence

The navigator-triggered sequence can be split into two parts. The first part is the initial learning phase, which is needed by the trigger algorithm to ascertain the patient's breathing pattern. The second part is the imaging phase during which the imaging data are acquired which are needed to reconstruct the anatomical images.

### Imaging phase

At the beginning of the imaging phase, the navigator is repeated at a constant interval *Scout-TR* to track the diaphragm position. As soon as the series of detected diaphragm positions fulfills the trigger condition, the sequence stops repeating the navigator and executes the first bloc of the anatomical imaging sequence (see Fig. 2). In the case of the interleaved TSE-sequence, a block acquires *n* echo trains-one per slice of the current concatenation. In the case of the single-shot HASTE-sequence the block acquires one complete slice. 400 ms after the anatomical data acquisition period has finished the sequence plays out the navigator again, to find the next suited respiratory phase. This cycle is repeated until all anatomical data have been acquired.

If the standard setting is used the trigger condition is:

i. The series of detected diaphragm positions must be rising; i.e. the patient must not breathe in.

ii. The latest detected diaphragm position must fall within a predefined acceptance window.

The respiratory curve shown in the Online display during the imaging phase is incomplete (Fig. 3). During the anatomical data acquisition period the navigator is not played out and therefore the respiratory trace can not be continued. As soon as the system detects the onset of expiration, the acceptance window is shown as a yellow box in the Online display. The vertical edge width of the yellow box is equal to the value of the parameter 'Acceptance window ±' on the Physio-PACE card. The central position of the acceptance window (the so-called trigger level) is either determined by the system during the learning phase or can be adjusted manually

## Learning phase

The initial learning phase requires 5 respiratory cycles. The learning phase is needed by the triggering routine to set the central position of the acceptance window during the imaging phase[2]. During the learning phase the breathing pattern is shown in the Online display. Beginning with the second complete respiratory cycle a red box visualizes the proposed anatomical data acquisition period. The location of these boxes is based on the parameter setting and the evaluation of the previous respiratory cycles. The horizontal edge width of the red boxes is determined by the aforementioned acquisition duration. The vertical position and edge width of each box was set that the box encloses the whole diaphragm trace during the proposed acquisition period. The parameter setting is fine for a certain respiratory cycle, if the data are acquired in the relaxed position near end expiration. If the horizontal edge width of the red boxes is comparable to, or greater than, one respiratory period (horizontal distance from maximum inspiration to next maximum inspiration), the measurement must be stopped and the acquisition duration must be reduced. This is necessary to avoid artifacts and a low trigger rate. In the case of the TSE-sequence a smaller turbo factor or a reduced number of slices per concatenation shortens the acquisition duration. In the case of the single shot HASTE sequence the base/phase resolution or the field of view in phase encoding direction can be reduced. In either case, increasing the bandwidth per pixel shortens the acquisition duration.

[2] *Note that even if the trigger threshold is set manually, a learning phase is needed since the central position of the acceptance window is not the sole function of the trigger threshold. The central position of the acceptance window always depends on statistic quantities calculated from the series of diaphragm positions measured during the learning phase.*

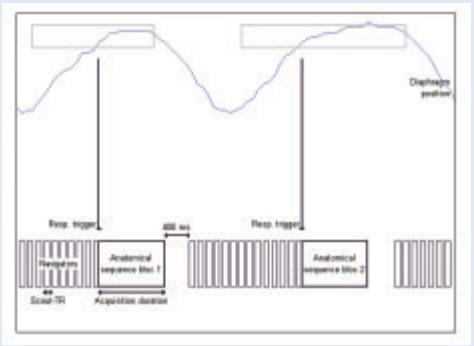


**Figure 2** *Timing diagram for the imaging phase of the navigator triggered sequence. The thin blue curve is the diaphragm position as a function of time. The upper gray boxes visualize the acceptance window. The acceptance window is interrupted while the patient breathes in, since the system never triggers during inspiration. On the lower left side the navigators are shown: these are repeated at a constant interval Scout-TR to track the diaphragm position. As soon as the detected diaphragm position falls within the acceptance window, the sequence stops repeating the navigator and executes the first block of the anatomical imaging sequence. In the case of the interleaved TSE sequence, a block acquires n echo trains – one per slice of the current concatenation. In the case of the single-shot HASTE sequence, the block acquires one complete slice. Acquisition duration is the time needed to execute the block. 400 ms after the anatomical imaging block is finished, the navigators are repeated again until the trigger condition is fulfilled within the next breathing cycle.*

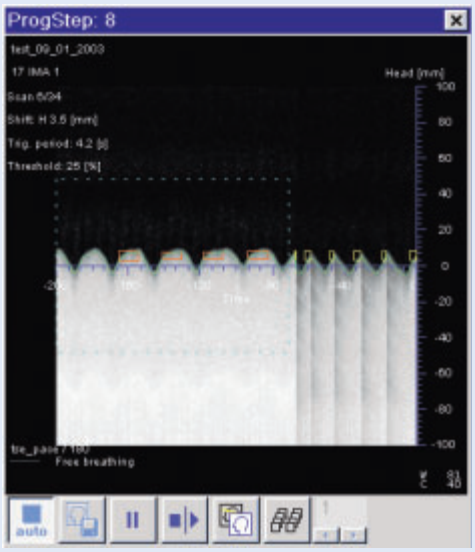



**Figure 3** *Respiratory curve of the Trigger option. The turquoise dotted window on the left (which shows the navigator position) marks the learning phase of the trigger algorithm. During the learning phase red boxes visualise the proposed anatomical data acquisition periods. The location of these boxes is based on the parameter setting and the evaluation of the previous respiratory cycles. The parameter setting is fine for a certain respiratory cycle, if the data is acquired in the relaxed position near the end of expiration. If the horizontal edge-width of the red boxes is comparable or greater than one respiratory period (horizontal distance from maximum inspiration to next maximum inspiration) the measurement must be stopped and the acquisition duration must be reduced. On the right half of the figure, the respiratory trace during the imaging phase is shown. As soon as the system detects rising signal (onset of expiration), the acceptance window is shown as a yellow box. If the detected diaphragm displacement (green curve) falls into the acceptance window, the basic anatomical imaging block is executed. During anatomical data acquisition the respiratory curve is not continued. The number of acquired scans in relation to the total number of scans to be acquired is shown in the upper left corner (here "Scan 6/34"). The trigger period is the median temporal displacement between two trigger events. If the system triggers once per respiratory cycle, the trigger period is equal to the respiratory period. The last image text line in the upper left corner shows the trigger threshold.*


**Proven Outcomes in MR.**

Penetrating. Scrutinizing. Head to toe. Front to back. And side to side. Tim (Total imaging matrix) takes it all in. And in the process, opens up countless new possibilities. Tim brings together, for the first time ever, 76 matrix coil elements and up to 32 RF channels. All of which can be freely combined in any way. The highest signal-to-noise ratio possible today, while still enabling seamless, whole-body imaging with a total FoV of 205 cm (6' 9"). Tim is not just another round of enhancements. But a transforming technology that does so much more. So you can, too. See for yourself at www.Siemens.com/Tim.

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# A Quantum Leap in MR Tomography: Tim [76x32]

**MRI is about to become radically faster and more flexible, enabling entirely new applications thanks to a powerful new partner: Tim – Total imaging matrix.**

By Carol Milano,
Dr. Christoph Zindel, M.D.

This fall, Siemens will be introducing Tim, a revolutionary new addition to the traditional MRI process. Tim, the unique Total imaging matrix technology, brings MR tomography greater performance than it has ever had before.

In the past, MR technology was limited to array coils offering a maximum of only eight receiving channels. Until Siemens introduced the unique IPA (Integrated Panoramic Array) concept in 1997, the possibility of varying the combination of coils for scanning larger areas of the body has been very limited or even nonexistent. Now, for the first time in the history of MR, the user can individually select the specific exams for the desired anatomy – and no longer has to deal with patient repositioning or coil reconfigurations. Tim features as many as 76 (!) seamlessly integrated coil elements, along with exactly 32 independent receiver channels. These can be used flexibly in any combination to create a whole-body imaging matrix, supporting a total field of view of 205 cm (6' 9"). Conventional metastases evaluation of the whole body, however, requires changing coils and repositioning the patient for each anatomical area of interest, e.g. head, thoracic, abdominal, pelvis, etc... With the introduction of Tim, workflow and patient comfort level are vastly improved by simplifying the MR process and shortening examination times. Both the matrix coils and the patient need only be positioned once for all desired exams, as multiple channels allow a unique and almost unlimited scanning flexibility.

## Scan times cut in half

Usually, even with the existing coil concept, only about a 150-cm field of view could be scanned with surface coils and a sufficient signal-to-noise ratio (SNR). For whole-body coverage, the patient needs to be repositioned, i.e. the coil setup has to be reconfigured. The only alternative, up to now, has been to perform whole-body MR imaging without surface coils, i.e. just with the integrated body coil, which, however, significantly reduces image quality. Thus, MRI technicians have always had to choose in the past between total body coverage and adequate image quality. Tim erases that difficult decision by allowing up to 100 percent more SNR. The result: up to 205 cm (6' 9") can now be scanned at maximum SNR – requiring only 12 minutes. That's a phenomenal time reduction of more than 50 percent!

Tim can help making accurate diagnoses, even for extremely complex imaging needs. Tim's flexibility means that if something unexpected is spotted, the region of interest can be expanded instantly, without any repositioning of the patient or any coil reconfigurations.

## Unlimited parallel imaging

Tim's reach is virtually boundless. Today, so-called Parallel Imaging (Parallel Acquisition Technique, PAT) already allows faster acquisition with high image quality. This is a distinct advantage, for instance, in MRIs of moving organs, because motion artefacts are significantly reduced or even eliminated. Unfortunately, the disadvantages of PAT include limited fields of view, usually based on the specific PAT coils required, and a finite number of receiver channels. Here, Tim shows its real added value. It removes all those negatives by allowing Parallel Imaging along the patient's entire body in a total field of view of 205 cm. The very highest PAT factors are now available in all three dimensions: from head to feet, anterior to posterior, and left to right. That means that the highest acquisition speeds and image resolutions can be achieved without the need for any specific PAT coils.

## Intelligent assistance

Tim goes even further to intelligently assist with MRIs: For the first time, it makes Parallel Imaging easy by recommending the maximum PAT factors for whichever application is selected. And the Tim Assistant helps finding the selected coil elements, correct patient position, and appropriate MR protocol, assuring the integrated Parallel Acquisition Technique (iPAT) configuration for each particular need. Siemens continues to uncompromisingly pursue its goal of truly optimizing workflow: With Tim's new Intelligent Coil Control, technicians can control all coils, both fixed and flexible, and their corresponding elements. This is all aimed at making Parallel Imaging easy and more efficient, as well as integrating it into the clinical routine.

In addition, with iPAT, Siemens offers two forms of PAT: GRAPPA (Generalized Autocalibrating Partial Parallel Acquisition) and mSENSE (modified Sensitivity Encoding), thus increasing flexibility for the different requirements of MR applications. Thanks to Tim and its broad iPAT capabilities, outstanding image quality is achieved along with high-speed acquisition performance and improved SNR.


*The first MRI system equipped with Tim Technology.*

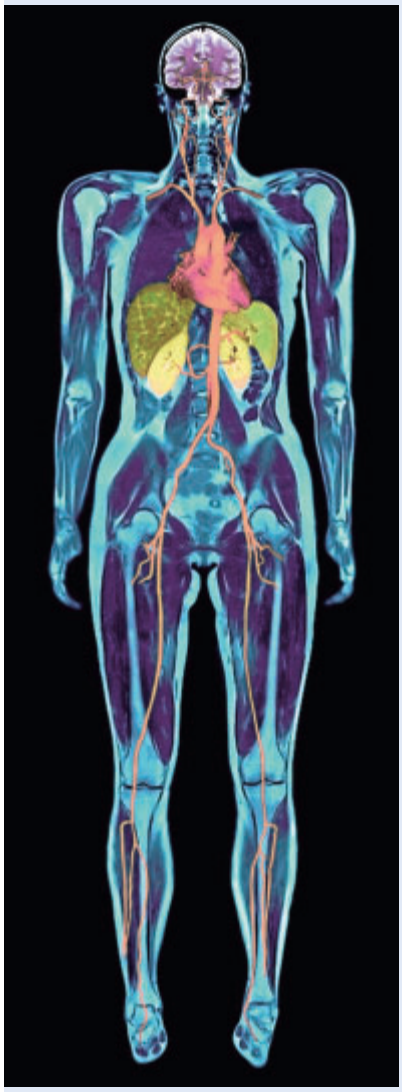
*Tim redefines the term "freedom in MRI" by taking a quantum leap beyond the boundaries of array coils to a breakthrough matrix coil concept.*

Tim features three performance levels: the top-of-the-line Tim [76x32] (i.e. 76 seamlessly integrated coil elements and 32 receiver channels), which not only accommodates clinical routine and demanding research, but is also open for all future applications, such as interventional procedures. Tim [76x18], with 18 anatomically optimized independent receiver channels, provides Parallel Imaging in the full 50-cm field of view, and Tim [32x8] for high-end clinical routine. There is a level for every need.

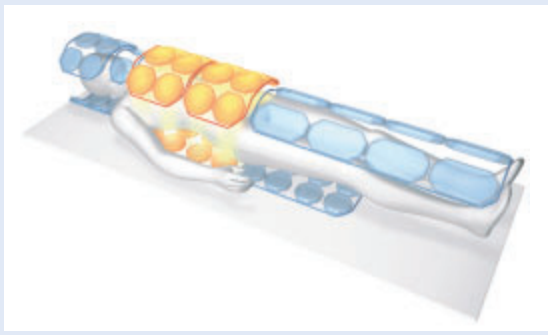
## World premiere

When and where can you meet Tim? Tim will make its debut at the 89th Scientific Assembly and Annual Meeting of the Radiology Society of North America, beginning in Chicago on November 30. Also in November, the first Tim systems will be installed at key facilities in New York and Tübingen, Germany. As part of a special publication on science and health innovations, Siemens recently used Tim technology to perform a whole-body scan on Hannah Stockbauer, one of the most successful female swimmers in German history. Hannah, 21, who won three gold medals this summer at the 10th FINA World Swimming Championships in Barcelona, is currently doing an internship at Siemens.

## Whole-body functionality with [76 x 32]

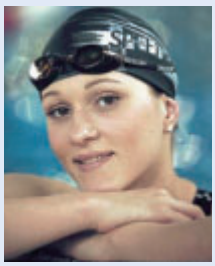


*German Swim world champion 2003, Hannah Stockbauer, in a whole-body MRI scan.*



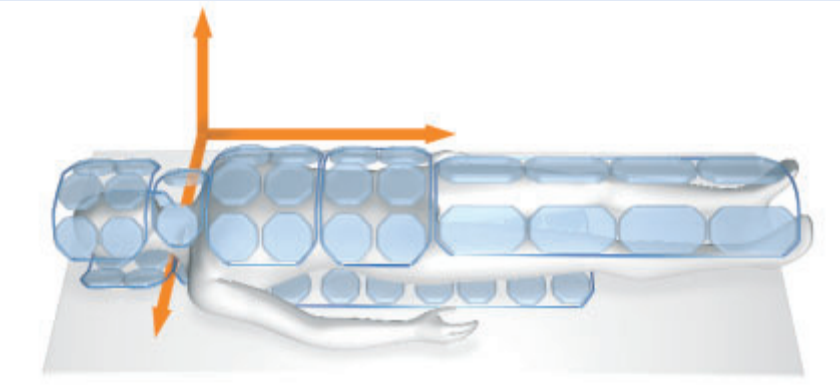
*Up to 76 seamlessly integrated coil elements and up to 32 RF channels combined to create one Total imaging matrix.*

Tim enables MR users to freely and flexibly combine up to 76 seamlessly integrated coil elements and up to 32 RF channels to one Total imaging matrix. No manual coil reconfiguration during the exam. No patient repositioning either. Giving them total, multi-channel whole-body imaging, seamlessly. If during the course of an exam unexpected findings appear, the anatomical region of interest can be expanded immediately. Tim enables streamlined true whole-body imaging with a total field of view (FoV) of up 205 cm (6' 9") – in surface coil quality and with up to 100 percent increase in signal-to-noise ratio (SNR). Tim opens up a whole new world of clinical applications, from whole-body to local MRI. New approaches for cancer staging, visualization of systemic diseases like rheumatic or vessel diseases, or MR angiography. Radiologists will see more than ever before: detailed morphology, leading to an unparalleled level of confidence in all physician's diagnoses while at the same time shortening exam times and streamlining workflow.



*Hannah Stockbauer*

## High-speed PAT Factors in all 3 dimensions



Redefined and optimized Parallel Imaging thanks to the new Total imaging matrix technology. With Tim, high-speed PAT factors (Parallel Acquisition Techniques) can be applied in all three dimensions. Supporting the highest acquisition speeds and image resolutions. Tim allows full iPAT functionality including iPAT² with PAT factors up to 12. Highest image quality is provided by up to 100 % more SNR for the most clinically exceptional and relevant images. And: no specific PAT coils are required. The Tim Assistant intelligently helps to make Parallel Imaging easy by recommending the appropriate PAT factors for the selected application.

*Redefining the concept of time: With Tim, matrix coils only need to be positioned once. This dramatically reduces patient set-up.*

*Easier for everyone: With Tim nearly all MR procedures can be performed as feet-first exams.*

## The benefits of Tim and MAGNETOM Avanto at a glance

**Clinical benefits:**

- Outstanding image quality with up to 100 percent more SNR, for whole-body and local MR imaging
- A total FoV of 205 cm can be scanned without any coil reconfigurations or patient repositioning
- Excellent temporal resolution with the strongest gradients currently available in the industry
- Unlimited Parallel Imaging seamlessly throughout the whole-body, and in all directions. No specific PAT coils required
- True whole-body MR enables first-ever optimized visualization and staging of systemic diseases

**Business benefits:**

- More patients per day due to the highest workflow efficiency
- More referrals due to greatly expanded MR services and applications
- Attracting more technicians due to most advanced MR system
- Less siting costs due to AudioComfort and less noise damping
- Always state-of-the-art technology with the MAGNETOM Evolve program
- More revenue with less operating costs, powerful return on investment

**Patient benefits:**

- Stress-free MRI with reduced exam time (patients need to be positioned only once, and a high-quality whole-body MRI can take as little as 12 minutes)
- Virtually all applications can be performed feet first, thus reducing patient anxiety
- Breath holding reduced by up to 50 percent
- 97 percent less acoustic noise with AudioComfort
- Less burden due to ultralight-weighted coils



www.SiemensMedical.com/MAGNETOM-World

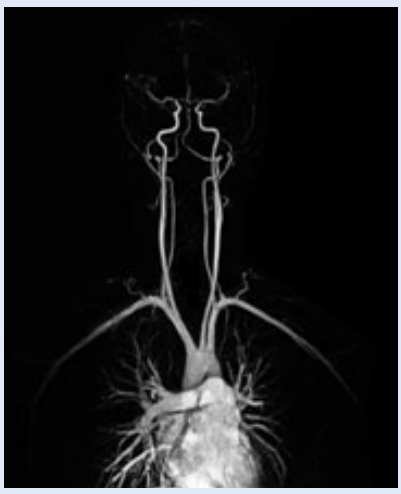
# Introducing MAGNETOM Avanto: The Revolution Begins Now

Carol Milano,
Dr. Christoph Zindel, M.D.

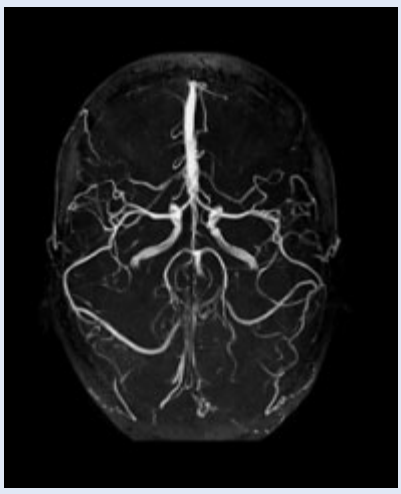
True whole-body functionality is now available, thanks to Siemens' new high-end 1.5T MRI system, MAGNETOM Avanto – the very first Tim system. Harnessing the power of Tim technology, MAGNETOM Avanto is able to deliver faster and more precise results than ever before for systemic diseases. This holistic approach provides benefits for many other examinations, such as clarifications of vessel and rheumatic diseases as well as preventional exams. Tim makes MAGNETOM Avanto not only more versatile, but also more efficient. As a result, MRI facilities can broaden their offerings and expand into other, totally new application areas. The state-of-the-art MAGNETOM Avanto offers performance without compromises: Having to choose between high performance and high acoustic noise levels or low performance and quietness – this decision is no longer necessary. With MAGNETOM Avanto's AudioComfort, the strongest and fastest gradient systems with field strength of up to 45 mT/m and a slew rate of 200 T/m/s are combined, with a reduction of acoustic noise of up to 30 dB(A), equal to 97 percent.

## Workflow automation

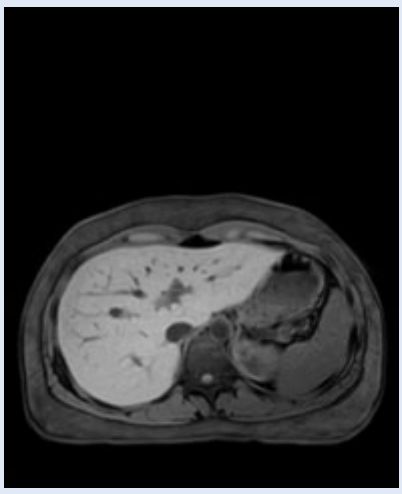
MAGNETOM Avanto is surprisingly easy to use. By intelligently automating the workflow path, it makes both the work environment and the staff more comfortable. The entire system, including hardware and software, together with the matrix coils and the 10 (!) table-integrated plugs, are consistent with Siemens' commitment to ergonomic design. This design virtually eliminates many time-consuming manual steps, including coil reconfigurations and patient repositioning, while significantly reducing table operation. The telescopic matrix patient table is perfectly suited for whole-body workflow and helps to increase the available workspace in the MR room. Tim helps MAGNETOM Avanto to accelerate patient setup, scan times and exams. Inline technology, enabling processing instead of post-processing provides immediate clinical results – in realtime – for procedures such as prospective motion correction (PACE), diffusion,



*Head-neck ce-MRA with excellent separation of the arteries from the veins.*



*High-resolution 3D Time of Flight (ToF) MR Angio with excellent visualization of peripheral vasculature.*

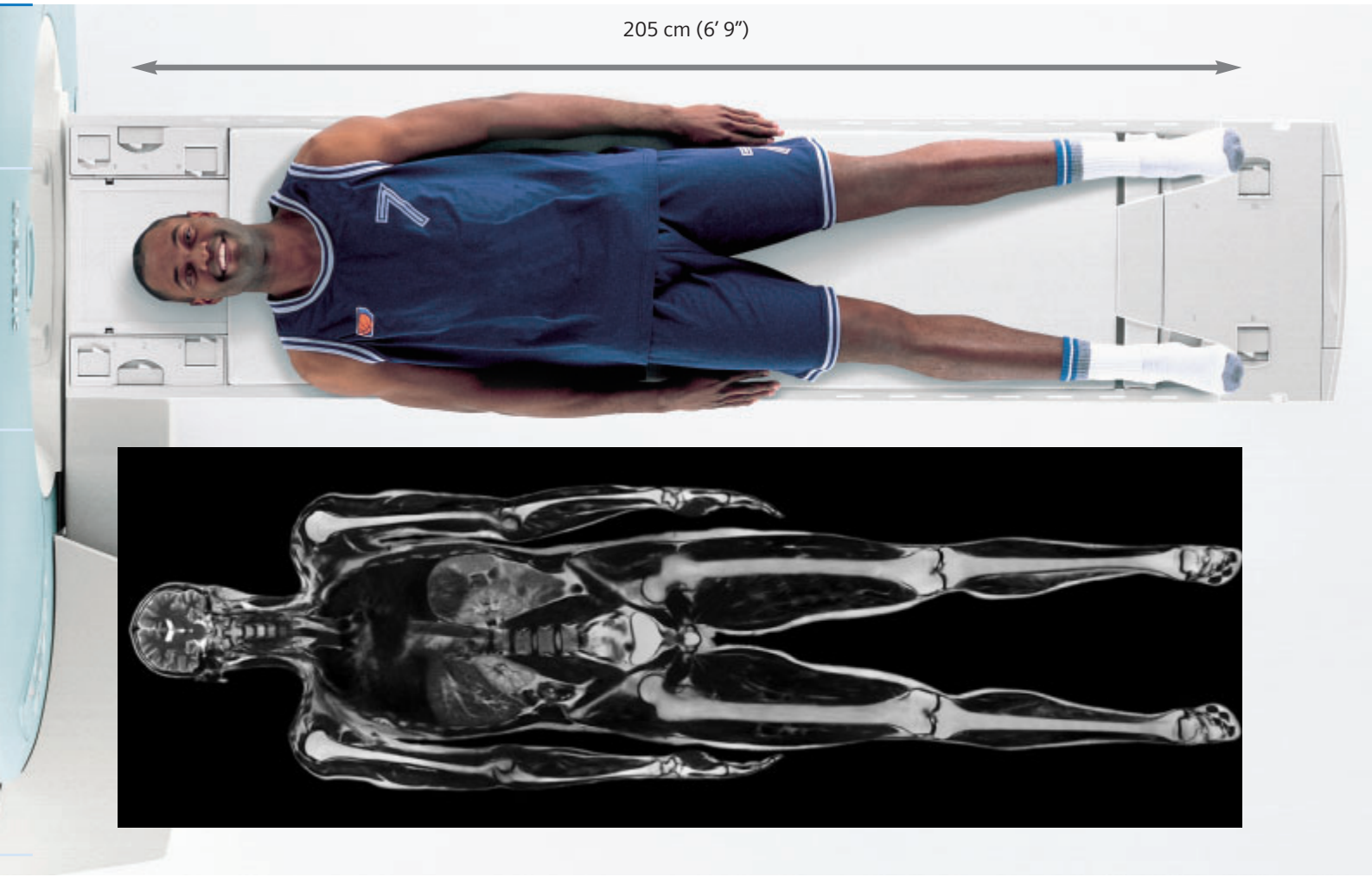


*T1-weighted FLASH 2D fat suppressed transverse image.*


perfusion, MR angiograms, and fMRI (BOLD), supporting also fast, precise visualization of systemic diseases. Another Siemens innovation, Phoenix, makes it possible to save, extract, and set up MR protocols in less than 30 seconds. With Phoenix, what you see is what you get: Just drag and drop a DICOM image and use the MR protocol to reproduce it. With the new AutoAlign, using a standard adult three-dimensional brain, automatic slice positioning in the brain is possible for the first time ever. AutoAlign helps to make MR brain exams more reproducible which is especially important for follow-up exams. In combination with Phoenix, it can be also used to distribute predefined MR protocols from one scanner to another within the same institution.

From a business perspective, MAGNETOM Avanto allows MR labs to do more with less: more patients per day, more referrals due to new applications, and higher diagnostic confidence as a result of the impressive image quality – all coupled with lower operating and siting costs. Another plus for the business side: Because Siemens has attained zero helium boil-off, there is far less

*MAGNETOM Avanto is the first system with Total imaging matrix technology. It features exceptional image quality by utilizing the highest signal-to-noise ratio possible. MAGNETOM Avanto has the most comprehensive and innovative application range available today. Tim has met his match.*




*MAGNETOM Avanto, the first Tim-operated system, enables whole-body imaging of up to 205 cm (6' 9") – in as little as 12 minutes.*

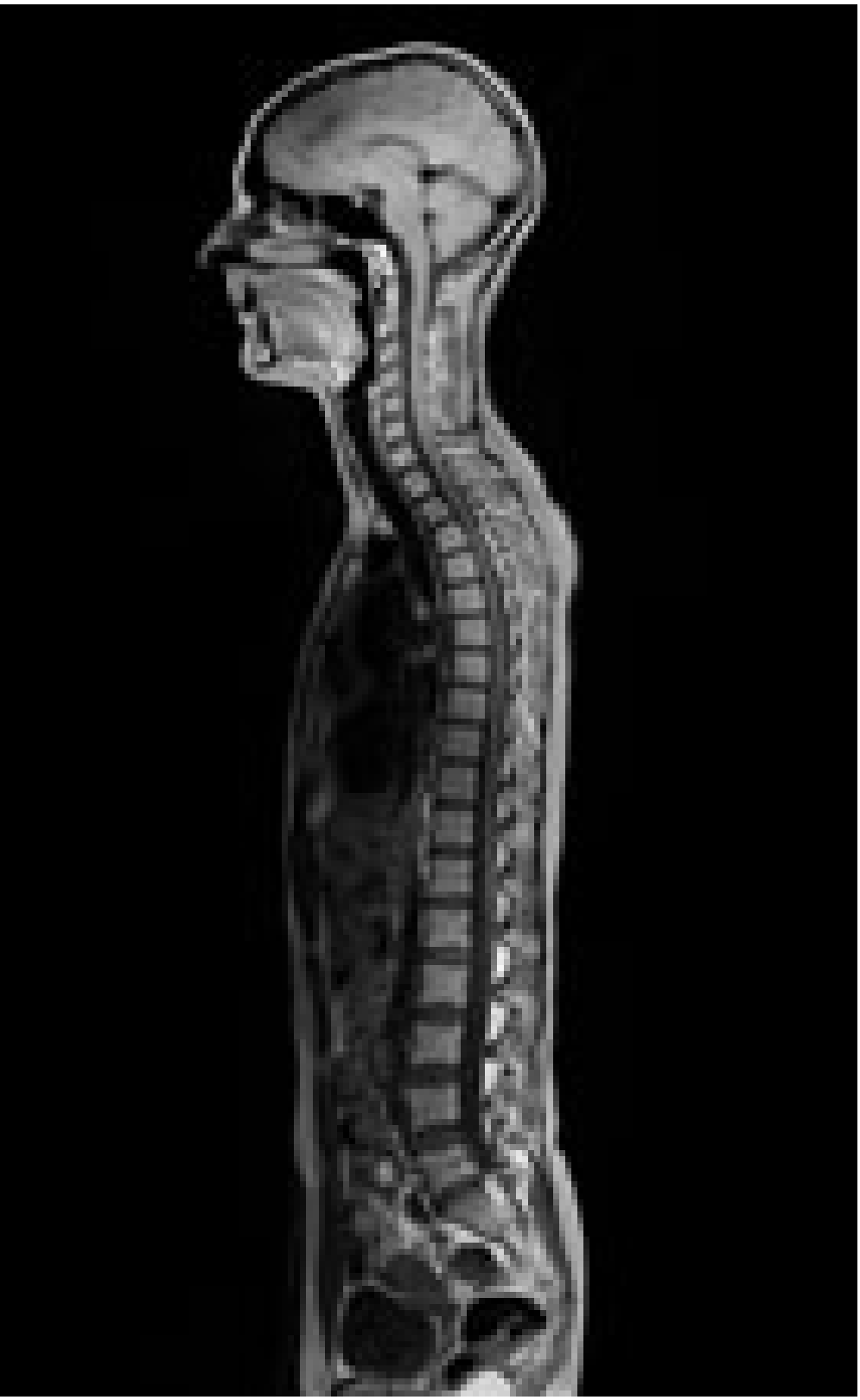
downtime for refilling the magnet, and more uptime for the system.

## Higher patient satisfaction

Often, patients become anxious because of the acoustic noise during an MRI procedure. They will be very grateful for MAGNETOM Avanto's AudioComfort concept, featuring multiple and integrated measures to significantly reduce noise levels. For example, special casting for gradient coils and magnet encapsulation help to achieve reductions of up to 97 percent without sacrificing the high-performance gradients needed for demanding applications. Therefore, ear protection or headphones are no longer mandatory. Patient comfort is also enhanced due to ultra-light-weight Body Matrix coils. Weighing only 950 grams, they are far more comfortable and will make a major difference to very ill cardiac or cancer patients suffering from pain. For claustrophobic patients, the fact that virtually all MR exams can now be carried out in the feet-first position is a critical factor. Most scans can easily be performed with the head outside the bore.

With MAGNETOM Avanto, exam times are shortened and acquisition speed is peerless – welcome improvements for both medical staff and patients. Frail patients will also be very relieved that breath-holding time is reduced by up to 50 percent.

MAGNETOM Avanto's examination table can be lowered down to just 47 cm (18.5 inches), making it accessible to virtually any patient, even children and the elderly.



*Flexible combination of seamlessly integrated coil elements for coverage of large anatomical areas. This entire CNS was imaged without patient repositioning or coil reconfiguration.*

Without any movement restrictions, the table also supports obese patients weighing up to 200 kilograms (400 lbs).

## The exciting future of MR

With MAGNETOM Evolve, the easy upgrade program from Siemens, MRI facilities will be able to keep up with any future changes in MR. And Siemens' integrated customer care program Life will be available to meet each customer's evolving needs. Evolution – and revolution – are what Tim is all about. The powerful, cutting-edge abilities of Tim and MAGNETOM Avanto are vanguards of change, integrating state-of-the-art medical technology, information technology, and clinical services to increase efficiency, satisfy patients, ease pressures on staff, and strengthen any facility's position in the medical sector. Tim has launched a new era, pushing MR to new limits while opening the door to an exciting world of possibilities beyond.

***Author:*** *New York-based medical writer Carol Milano has contributed to the New York Daily News, Los Angeles Times, Science and Health, and Woman's Day, as well as numerous trade publications and online magazines for the medical profession. She is also a longtime adjunct professor at New York University and the author of two business books.*

***Author:*** *Dr. Christoph Zindel, M.D., is Director of Segment Management at Siemens Medical Solutions' MR division.*

# Imaging the Whole Body – Viewing the Entire Person

**Tim – Total imaging matrix – offers exactly what Tübingen radiologist Claus Claussen wants: magnetic resonance imaging of the entire body in a single examination – faster, simpler, and quieter than ever before.**

**By Dr. Martina Lenzen-Schulte, M.D.**

One can see the Swabian Alps from the top of the Schnarrenberg, the site of the Tübingen University Hospital. When autumn fog clouds the view, Claus Claussen, director of the radiology department, takes it in stride. The radiologist has had many years of success in his field, and now it appears as though the last mists that had prevented full views into the human body are dissipating. In November, the first Tim system was installed at the well-equipped Tübingen University Hospital. Besides Tübingen, New York University is the only other hospital currently evaluating this groundbreaking technology. Tim opens new horizons in every sense of the word. Tim, which stands for Total imaging matrix, is more than just a new development; it is a revolution in magnetic resonance imaging. "76 seamlessly integrated matrix coil elements and signals derived across 32 receiver channels builds the technical framework for this new system," stated Claussen in an interview prior to the system's premiere at his hospital. It was clear that he wanted to provide additional details on what was behind these indicators.

"For the first time since the introduction of magnetic resonance imaging, Tim enables us to create a seamless image of the entire human body – up to a total of 205 centimeters."
Why is this important, and for whom? "Primarily for the patient," says Claussen, the physician. The problem with conventional solutions is that various regions of the body have to be examined in sequence using different local coils. To evaluate the entire body, the individual images had to be arranged in order. He calls it "patchwork", in the truest sense of the word. For example, two examinations are required just to obtain the pelvis and knee. This means that the patient has to be repositioned, which is cumbersome. For older and frail persons, accident victims, or the most seriously ill, repositioning may be stressful, sometimes troublesome, or in the worst case even painful. Additionally, the physician has to look for the appropriate local coil and position it on the patient – a continuous loss of time. The speed Tim uses to display the entire body simplifies the examination for more than just the patient. "Tim helps the physician and hospital personnel to save a lot of time," says Claussen, the departmental director, who cannot ignore the question of efficiency within his department. "Tim enables us to forget about all the intricacies. This significantly improves clinical workflow and enables us to dramatically increase patient throughput, all with excellent image resolution and the best possible image quality."

**»Tim simplifies the examination for more than just the patient.«**

MAGNETOM Avanto is the name of the first MRI system to use the revolutionary Tim technology; it also provides many additional advantages. "Again and again," said Claussen, "we as physicians have emphasized

*Dr. Claus D. Claussen is the Director of the Diagnostic Radiology Department at Tübingen University Hospital as well as Professor of Radiology at the Eberhard Karl University in Tübingen, Germany.*

*Dr. Claus D. Claussen, a champion of interdisciplinary perspectives, works in close cooperation with medical solution providers.*

how greatly noise affects the patient during an MR examination. The constrictive nature of conventional systems, especially when performing head examinations, is very uncomfortable for claustrophobic patients."

Siemens has implemented these requests: "Faster and quieter" became the watchword. A 97 percent reduction in noise while retaining the most powerful gradient system enables new real-time applications in MR and results in significantly higher patient comfort.

This is only one example for a philosophy of developing products by the customer for the customer. Physicians at the radiology department in Tübingen, working in a team with Siemens, proposed suggestions on what they felt was most important. "This type of cooperation is much more than an exchange of knowledge," says Claussen, a driving force behind this long-term partnership, "it is based on understanding and trust between people."

If Tim and MAGNETOM Avanto finally present the solution for seamlessly imaging the entire human body, it means that Claussen, the diagnostician, will finally be able to obtain a single view of the entire person: "There is a reason we speak of a vascular system, a nervous system. It is not a single blood vessel that becomes diseased and is detected due to localized changes in the heart, carotid artery, or the brain. Vascular disease occurs everywhere, is systemic, from head to toe throughout the entire organism." In light of all the tangible changes to the associated system, a whole-body examination provides far better diagnostic results for local medical pathologies than in the past – and with no additional system expense. Otherwise, the ability to image the entire body in a single examination will drastically simplify the search for metastases in cancer patients.

As a researcher, Claussen sees far beyond the diagnoses currently available. "We are already past the point of imaging morphology, the mere anatomy of the body. We can already display functions, the physiology of organs." In addition to the shape of the heart, the muscle's vitality and the blood flow can be determined from the image.
The consistent use of integrated Parallel Acquisition Techniques (iPAT) enables Tim to bring together speed and image quality within seamless whole-body imaging, and there is reason to believe that much more will be achieved. "We hope to penetrate the metabolic level of the organ. While it may appear to be a utopian dream, our goal is to display cellular activity down to the molecular level of detail." Claussen intends to follow his vision, which is beyond what is possible today. As a scientist and dean of faculty, he knows only too well that these goals require more than simply implementing technology. "If we can obtain an image of the entire human body using Tim, we also have to merge the various technical disciplines. Arteriosclerosis is not limited to the heart, and therefore its diagnosis should not be limited to a single organ." In Tübingen, research on cardiac diseases has seen cardiologists and radiologists working together for quite some time, to the benefit of both. Claussen sees himself as the representative of this cross-departmental group, an ideal platform for the integration of the individual disciplines. And Tim symbolizes interdisciplinary approach, which goes beyond stereotypical in-the-box thinking and views the patient as a whole. For this reason, looking back at these ancient medical traditions may be permitted – no matter how innovative the technology.

## Professor Dr. Claus D. Claussen

***Director of the Diagnostic Radiology Department at Tübingen University Hospital:***

*From 1966 to 1971, Professor Claussen studied medicine in Erlangen and Heidelberg, Germany. From 1973 through 1978, he trained in radiology at Heidelberg, and then served as Senior Physician at the Hospital of the Free University of Berlin (now Charite Hospital at Humboldt University). In 1988, Claussen was named C-4 Professor of Radiology at the Eberhard Karl University in Tübingen, and became Director of the Diagnostic Radiology Department.*

*He has been a member of the Tübingen University Senate since 1998, and in 2000 was elected Dean of the Medical Faculty. Professor Claussen is a member of many national and international professional organizations. From 2001 through 2003, he was President of the German Radiological Society, and will serve as its vice president from 2003 through 2005. He is the editor and associate editor of significant professional journals, and is a subject matter expert for the German Research Society. As Chairman of the Supervisory Board for the "University of Tübingen Clinical Studies (KKS)" coordinating center, he is actively involved in implementing quality standards for clinical research.*

***Author:*** *Dr. Martina Lenzen-Schulte is a physician. As a medical journalist, she has published articles in many well-known scientific collections and magazines.*

# 2nd Annual MAGNETOM World Summit September 17-19, 2003

MAGNETOM World

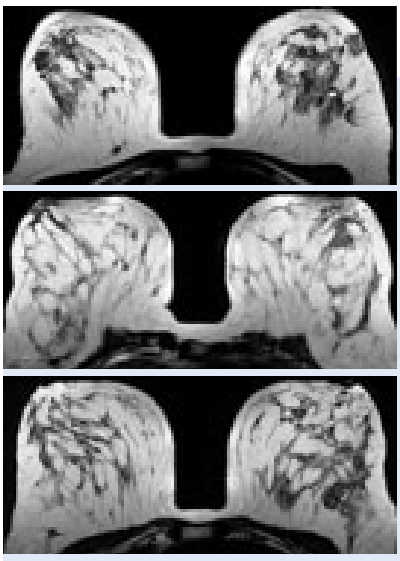
# 18th Thursday

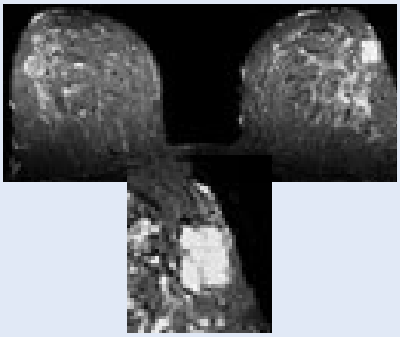

**Dr. Heinrich Kolem,** President of Siemens MR opened the meeting by describing MAGNETOM World summit as a communication platform where customers create a network in which they can learn from each other about clinical routine applications. It was also a great opportunity for Siemens to understand the needs of customers and use this opportunity as requirement engineering for future product development.

Vice-President of Strategic Accounts in USA, **Les Friend,** presented an outline of business at Siemens and Siemens Medical Solutions, demonstrating the evolution from past to present, as well as the future direction. He stressed the innovation and financial strengths of the company, defining it as a competitive global partner bringing cutting-edge technology to its customers. The US is the largest market for Siemens and Siemens has around 70,000 employees involved in many production and service areas, from electronics and IT to medical devices. Siemens is the third largest R&D spender in the world. Medical Systems is the number one solutions provider in the world, boasting a full spectrum product portfolio and workflow enhancement tools like *syngo*, Soarian and Sienet.

Miami

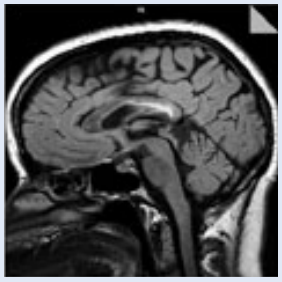

**Prof. Heinz Otto** from Evangelische Clinic in Gelsenkirchen provided theoretical information and also case reports from daily routine MR imaging of the breast. He started with explaining the indications for breast MR imaging. He added that the superiority of MR lied in the capability of combining the morphological information and temporal information. He stressed the vital importance of iPAT in breast imaging which can improve the diagnosis due to the fact that it provides higher spatial resolution images in the same time frame. Professor Otto uses iPAT to improve the spatial resolution in breast imaging. "iPAT is the future of breast MR" was his final verdict.



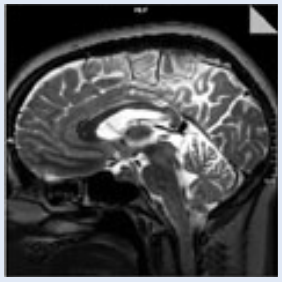


*Multiple fibroadenomas*
*T2 iPAT images without and with fat suppression.*

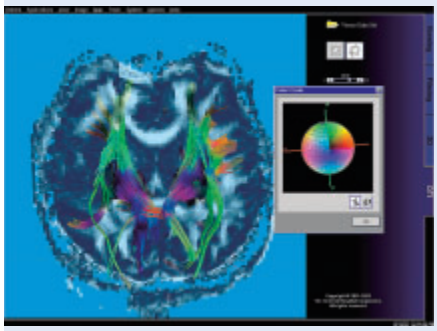

MR Application Business Development Manager, **Abe Padua,** talked about the clinical applications for 3 Tesla. He showed impressive results obtained with MAGNETOM Trio systems for advanced and routine neuro, vascular, body, orthopedic applications. He also stressed the importance of iPAT with 3 Tesla. He concluded by stating his belief that the Siemens ultra high-field system MAGNETOM Trio had become a clinical system in an environment where 3T systems are still perceived as a research tool.



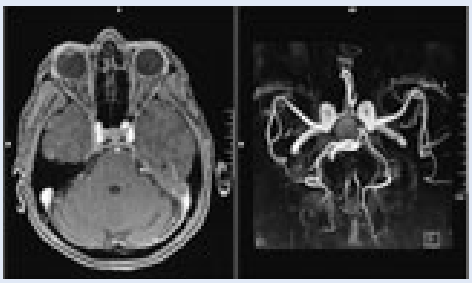
*3D Flair Isotropic 1mm.*



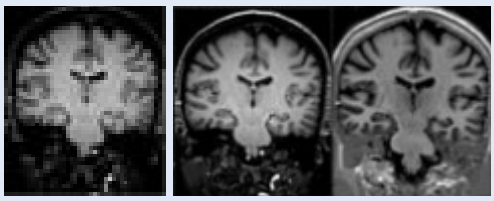
*3D TSE Isotropic 1mm.*



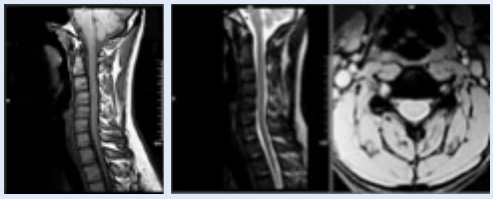
*Tractography*



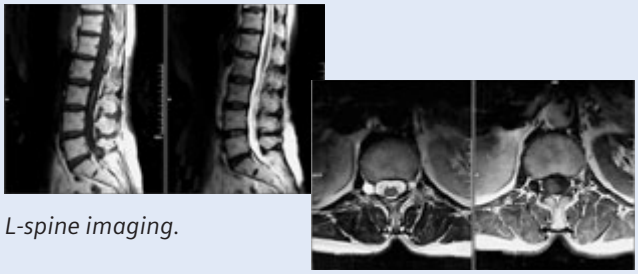
*512 matrix at 0.8 mm slice*
*4 slabs 6 minutes.*



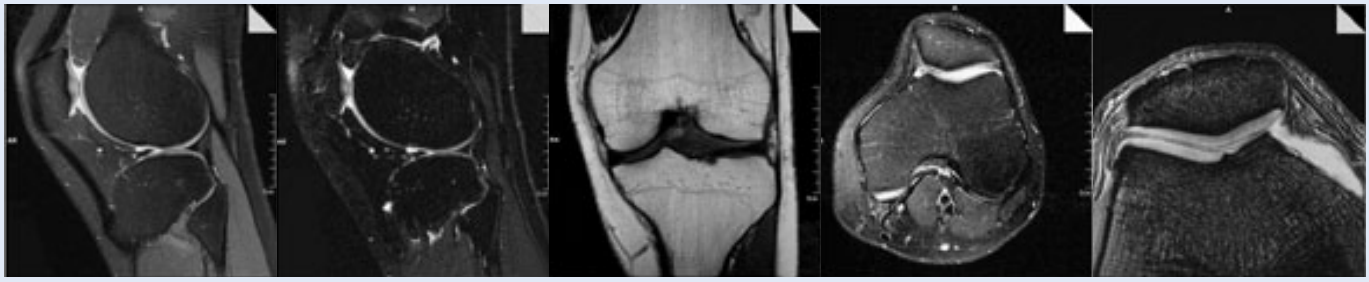
*Allegra T1 contrast.*



*C-Spine using Neurovascular Coil.*

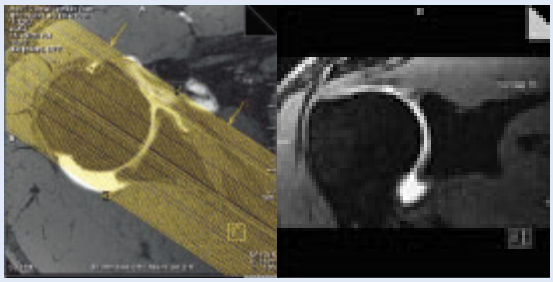


*L-spine imaging.*

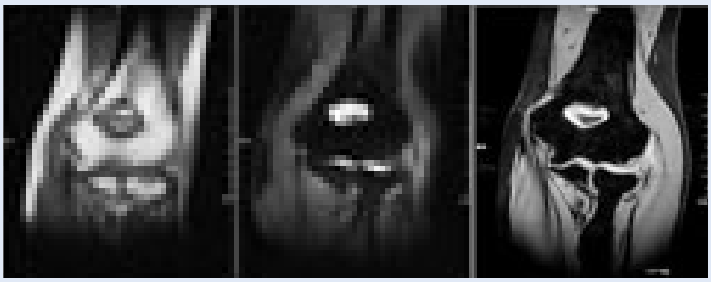


*3T Knee imaging.*

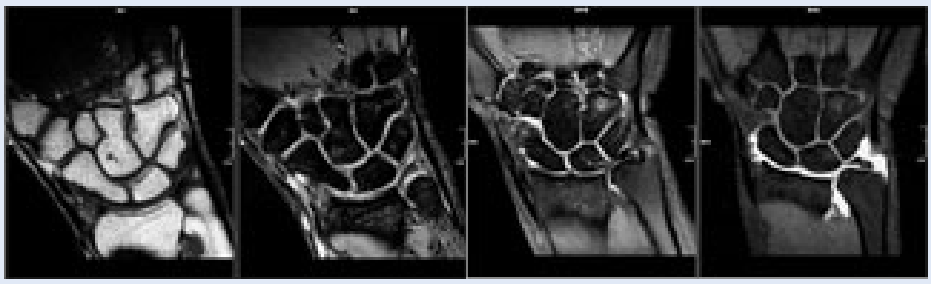
*3T Shoulder imaging.*



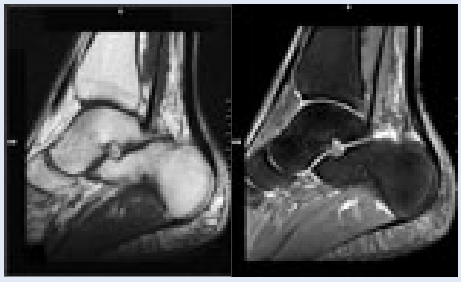
*3T 3D Shoulder imaging and MPR.*



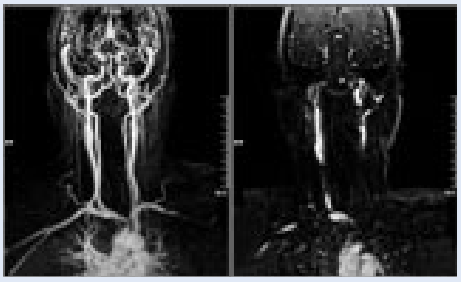
*3T Elbow imaging.*



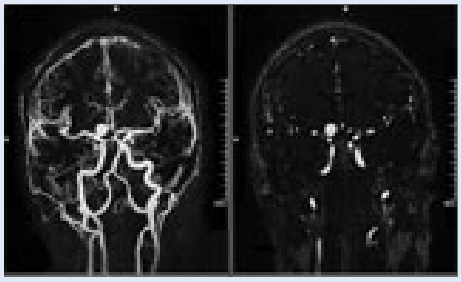
*3T Wrist imaging.*



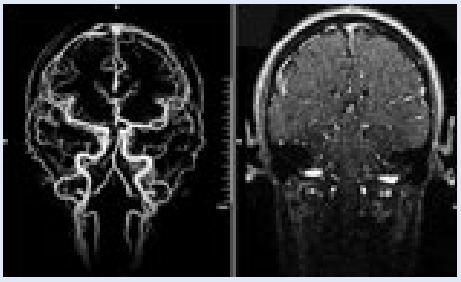
*3T Ankle imaging.*

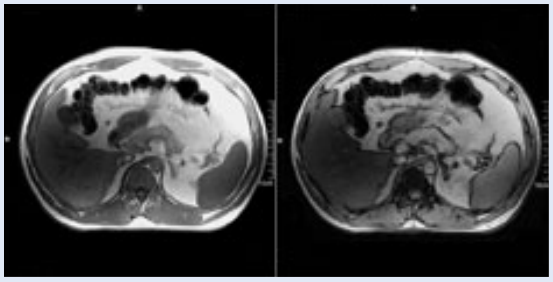


*3T Head-neck MRA.*

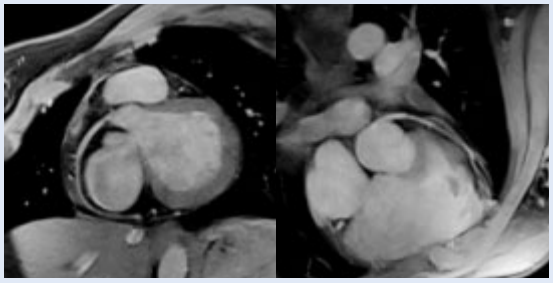


*3T Circle of Willis MRA.*

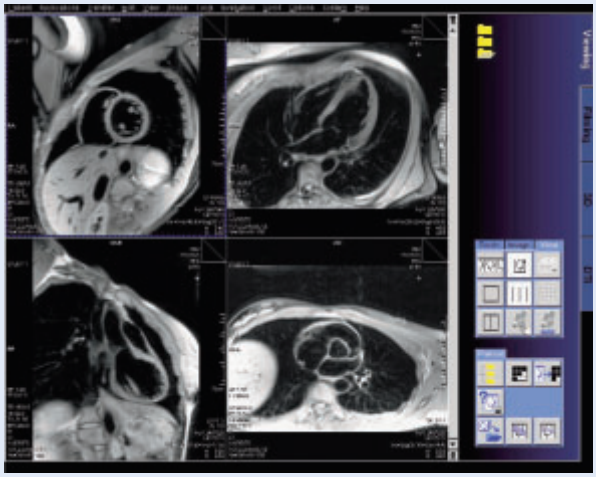




*3T T1 Abdomen*
*In-phase* *Out-of-phase*



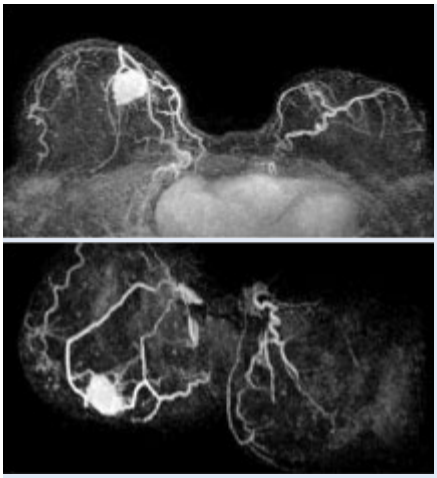
*3D FLASH with fatsat*
*TR/TE 112/1.5 ms, Pixelsize: 0.9 x 0.9 x 1.2 mm.*



*Dark Blood Technique.*

**Dr. Bruce Porter** from First Hill Diagnostics talked about the rapidly growing and clinically unique area of breast MR imaging, providing an excellent summary of Siemens breast MR solutions. The recent sequence techniques like "views" have improved the diagnostic efficiency in his clinic. He mentioned the different approaches of researchers and clinical radiologists in terms of choosing between higher temporal or spatial resolution. He said that he preferred bilateral examination of the breast with images having isotropic voxels. Dynamic breast MR is a technique to see and evaluate angiogenesis. Quantum gradient upgrade has brought advantages in imaging performance capabilities of the system. Maestro class and iPAT brought tremendous work flow and image quality improvements*. He also stressed the importance of computer-aided diagnosis using the temporal resolution information helping the differential diagnosis between malignant and benign lesions. His choice of biopsy method was for high-resolution ultrasound guidance following an MR in which he had obtained the necessary information regarding the location and perfusion characteristics of the lesion. Significantly, STIR sequence could be used to detect lymph node pathologies. For breast imaging, MR is one of the most powerful recent diagnostic tools, which is becoming increasingly available.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

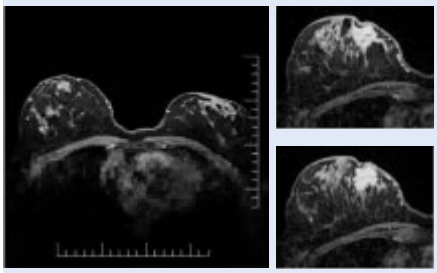


*Dynamic "VIEWS":*
*MAGNETOM Harmony with Quantum gradient system (1.0 T):*

*Dynamic: high temporal- and high spatial-resolution.*

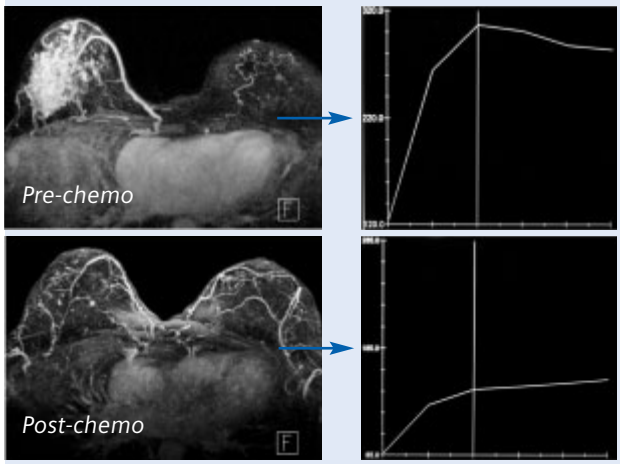
*Enhancement kinetics; CAD analysis.*

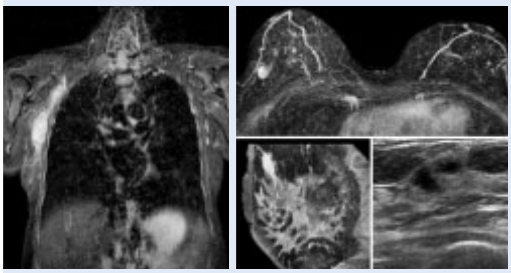
*Near-isotropic voxels:*
*High quality 3-D MIP and MPR.*



*Infiltrating ductal carcinoma:*

*high-resolution VIEWS (0.8 x 0.8 x 0.6 mm).*



*Occult Ca:*

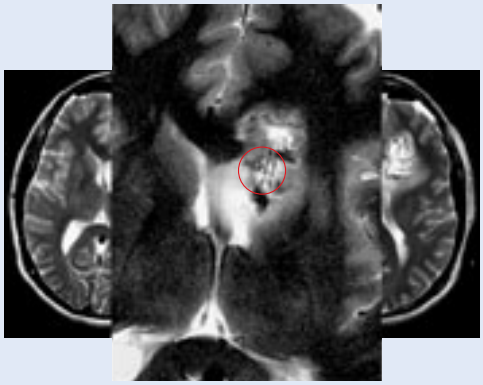
*Malignant adenopathy, negative ultrasound.*

- *Breast MR is a powerful diagnostic tool and is increasingly available.*
- *Current technology allows a near-ideal exam: high spatial- & high temporal-resolution.*
- *CAD facilitates breast MR interpretation and improves detection of subtle lesions, exam reproducibility, and image quality.*
- *Breast MR will become a standard, frequently used, clinical study in the near future.*

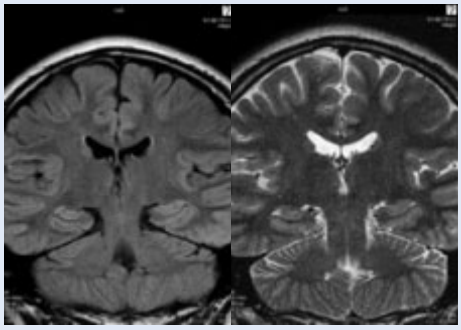
**Dr. Ed Knopp,** from New York University Hospital, presented trends in neuro-imaging and clinical use of 3 T. He said that 3 T enhances spatial resolution and does it in a clinically acceptable time. He introduced the clinical protocols he uses with 3 T MAGNETOM Allegra system and gave detailed explanation of clinical use of the protocols and sequences. In spectroscopy, smaller voxel size was an additional result achieved by the 3T systems, as was minimized susceptibility artifacts with diffusion-weighted sequences. Dr Knopp also talked about advanced imaging techniques such as fractional isotropic map, tractography with 3 T, perfusion maps, and spectroscopy with small voxels. He ended with the observation that "3 T is a practical clinical reality in our center with 18-20 cases per day".

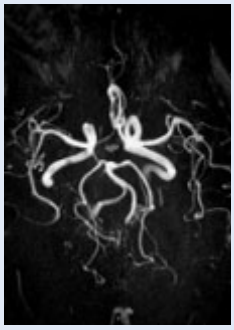
## High-Field Imaging Protocols

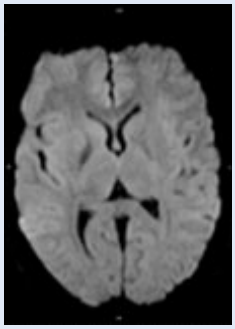
- **Routine Brain**
  - MPRAGE (axial acquisition)
    - Reformatted in Ax & Sag
  - Axial FLAIR
  - Axial T2
  - Axial Trace Diffusion
- **Contrast Brain**
  - Medical
    - Sagittal T1
    - Standard dose Gadolinium
    - Axial T1 – Gated
    - Axial FLAIR
    - Axial T2
    - Axial Trace Diffusion
- **Contrast Brain**
  - "Surgical"
    - Sagittal T1
    - Standard dose Gadolinium
    - Axial T1 – Gated
    - MPRAGE (axial acquisition) - Reformatted in Ax & Sag
    - Axial FLAIR
    - Axial T2
    - Axial Trace Diffusion
- **IAC**
  - Coronal T1
  - Half Dose Gadolinium
  - FS Ax T1
  - Cor T1
  - Ax FLAIR
  - Ax T2
  - Axial Diffusion
- **Pituitary – Dynamic**
  - Sagittal T1
  - Coronal T1
  - Dyn Cor T1
  - Half dose Gadolinium
  - Dyn T1's (5 sets)
  - Cor T1
- **T1 MPRAGE**
  - 224 mm Slab (1mm partitions) Axial
  - 210 FOV
  - 512 matrix (interpolated)
- **T1 SE (post Gado – Gated)**
  - 20 5 mm slices
  - 210 FOV
  - 512 matrix (interpolated)
- **Axial T2**
  - 20 5 mm slices
  - 210 FOV
  - 512 matrix (interpolated)
- **Axial FLAIR**
  - 20 5 mm slices
  - 210 FOV
  - 768 matrix (interpolated)
- **T2 TSE Hi Res**
  - 13 Slices
  - 180 FOV
  - 640 matrix (interpolated)
- **T1 TSE Dynamic**
  - 8 slices
  - 200 FOV
  - 512 matrix (interpolated)
  - 44 sec scan time
- **3D TOF MRA**
  - 3 overlapping slabs
  - 220 FOV
  - 1024 matrix (interpolated)
- **Diffusion (Trace & ADC)**
  - 20 Slices
  - 210 FOV
  - 256 matrix (interpolated)
  - B: 0, 500, 1000
- **Perfusion**
  - 1 second temporal resolution
  - Whole brain coverage (if needed)
  - 256 matrix (interpolated)
- **Spectroscopy**
  - Small voxel size (0.5mm)
  - Long and short TE



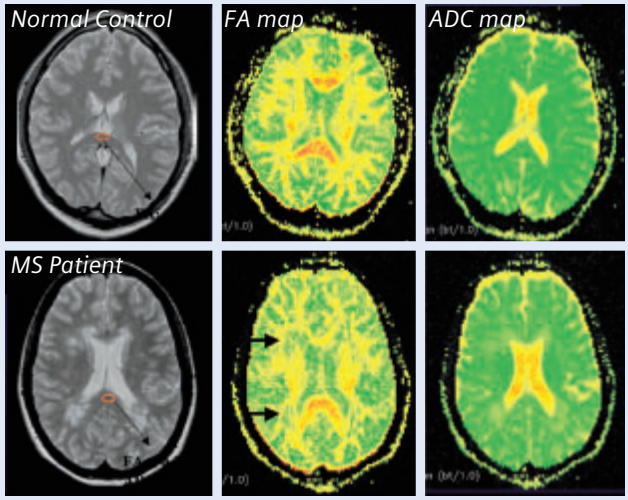
*Post-op T2.*



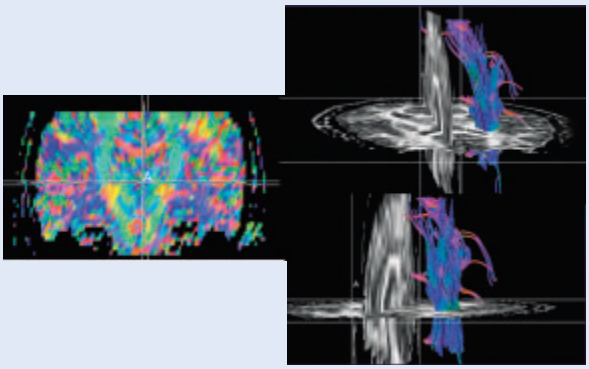




*3 T diffusion imaging.*

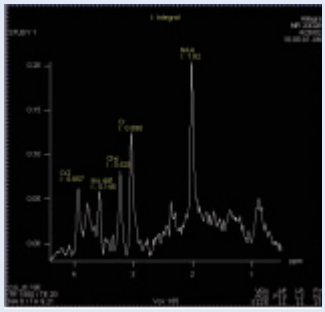



*Diffusion Tensor in MS.*

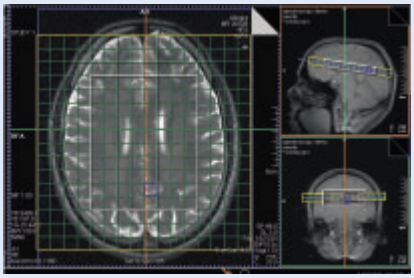


*Diffusion Tensor Imaging Fiber Tracking.*

*Ultra High-Field spectroscopy.*



*3 Tesla MAGNETOM Allegra CSI-STEAM, TE = 20 ms, TA = 3' 12 s.*



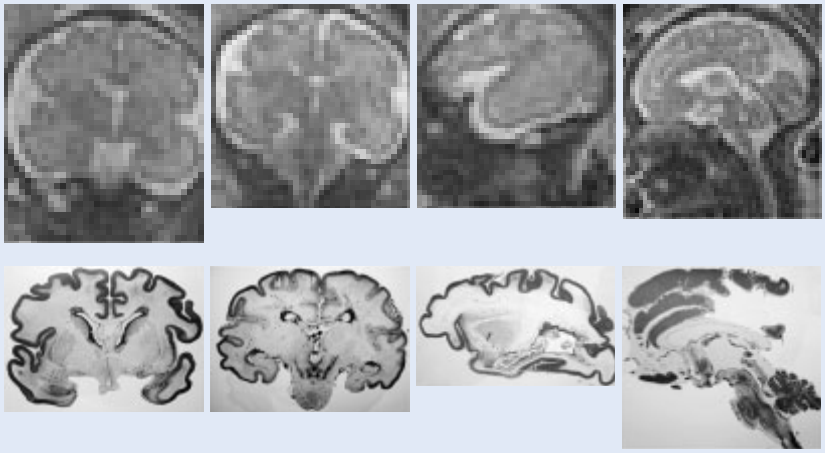
*Higher SNR.*

*Improved Quantification.*

*Higher Spectral Resolution.*

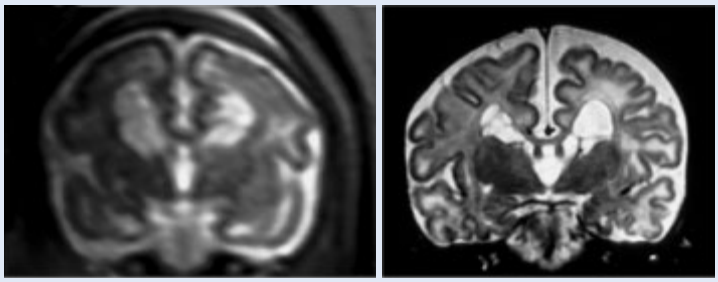
*Higher Spatial/Temporal Resolution.*


**Dr. Robert Zimmerman,** from the Children's Hospital of Philadelphia, introduced his talk with reference to the unique character of pediatric imaging with the patient population ranging from a premature 14 ounce fetus* to a 400-pound adolescent. He surveyed the large spectrum of diseases from metabolic diseases to white matter diseases and developing brain changes. SAR issues, he stated, were one of the major problems in pediatric MR imaging. Dr. Zimmermann showed some pathological cases with the protocols used and sequence details for pediatric imaging. He added that the image quality was continuously improving with MR. For cerebro-vascular diseases in the pediatric population, which differs from the adult in terms of etiology, he said that MR had revolutionized the diagnosis of diseases with diffusion and ADC maps. He also described his experience with arterial spin labeling and diagnosis of tumors with MR. Here the use of spectroscopy was invaluable, in his experience. The combination of imaging and spectroscopy would increase specificity. The last topic he covered was metabolic diseases. He concluded his talk by saying that the intention was to move to 3 Tesla from 1.5 Tesla, with the hope, of course, that SAR issues are resolved, as this was the most important obstacle in pediatric imaging.



*Fetal imaging* – MRI*
*32 weeks gestation.*

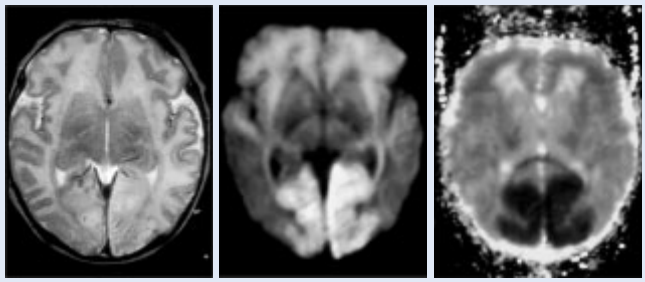
*Brain development.*



*Coronal T2*
*32 week fetus.*

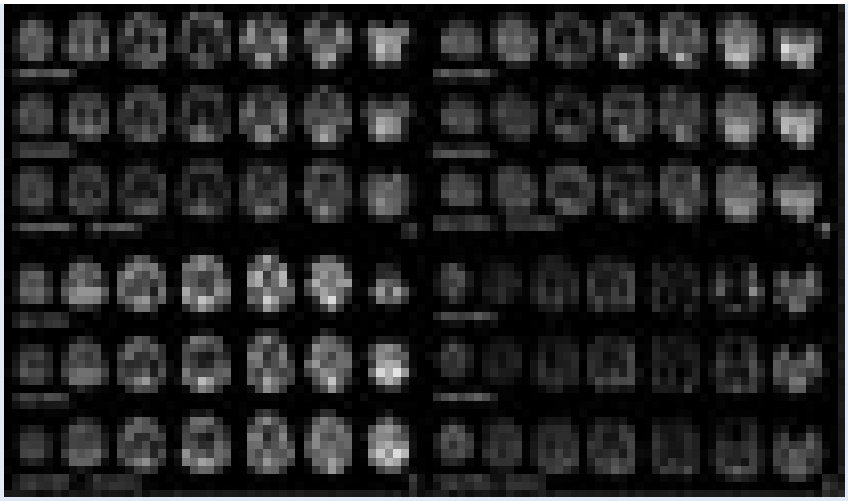
*Coronal T2*
*6 week infant.*

## Hypoglycemic brain injury acute – 3 day female



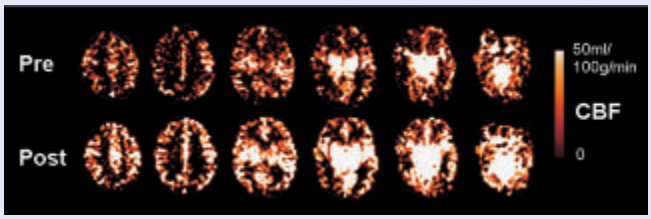
*Axial T2.* *Axial Diffusion.* *Axial ADC.*

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured. The safety of imaging fetuses, infants has not been established.*



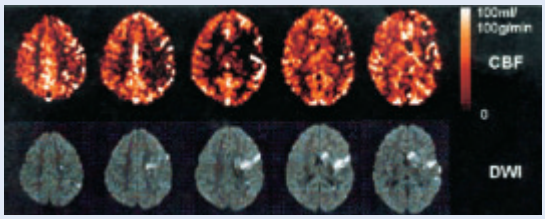
*Child vs. Adult perfusion images.*

## Application in neonates with congenital heart disease



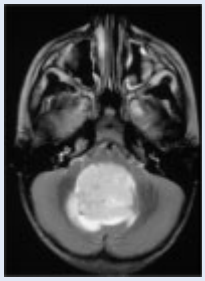

*Neonatal perfusion (5 days) pre and post hypercapnia.*

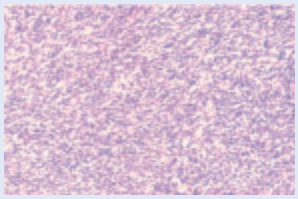
## Arterial spin labeling

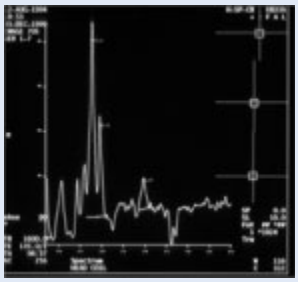



*Acute infarction.*

## Proton spectroscopy Primitive neuroectodermal tumor







*T2 5 year old female.*

*single voxel*

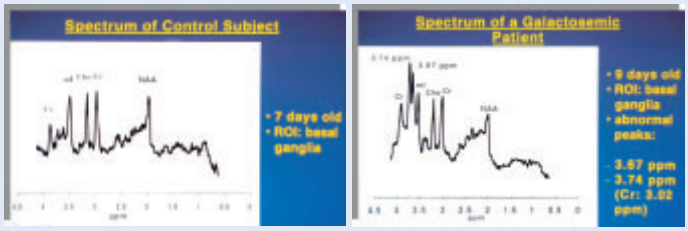
*TE 135 msec*

*choline*

*taurine*

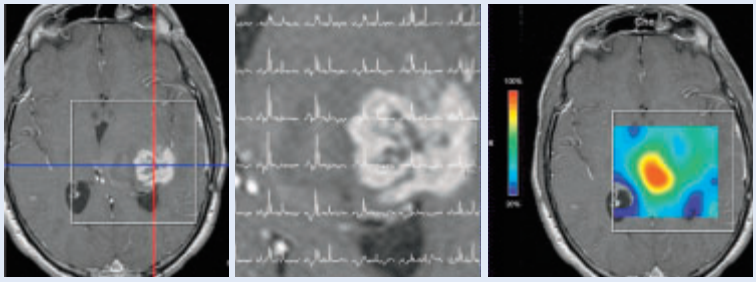
*Naa lactate*

## Clinical indications Pediatric proton spectroscopy

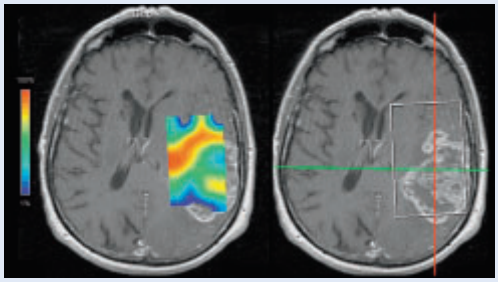



*Metabolic disease abnormal metabolites.*

**Dr. Lester Kwock,** from University of North Carolina Hospital, has 20 years of experience in spectroscopy, mostly in neurological patients. "Siemens has done a good job in recent years particularly with *syngo* in creating the tools to observe patterns of diseases with spectroscopy". He explained the use of short and long echo time examinations. He defined the tendency in spectroscopy towards multi-voxel examinations rather than single voxel. He showed some examples that made the advantages of spectroscopy clear, such as differentiating between primary and metastatic lesions, diagnosis of recurrent tumors and differentiation of radiation changes or reactive changes. He also showed some examples of prostate spectroscopy. He was very happy with his MAGNETOM Sonata system and highlighted that 3D CSI with Sonata would take less time than with other scanners and provide useful, reliable information with good spectral results. A further interesting contribution he made was the addition of perfusion measurements to his examinations, which improved diagnostic certainty. A very interesting approach was the prostate examination he had been trying to implement in his clinic without endorectal coils.

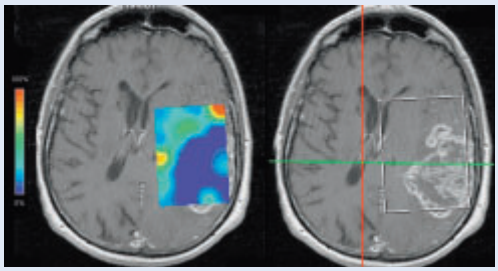


*CSI of Gliobastome multiforme.*

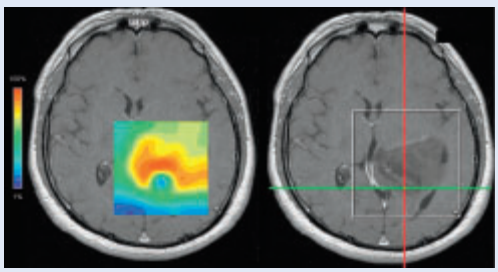


*Choline map.*

**Gliobastome multiforme.**

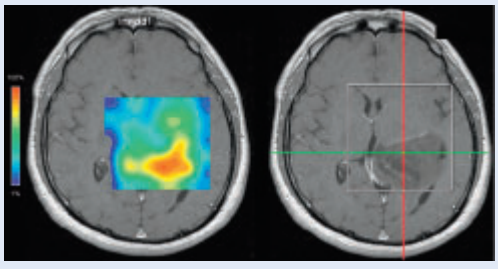


*Myoinositol map.*

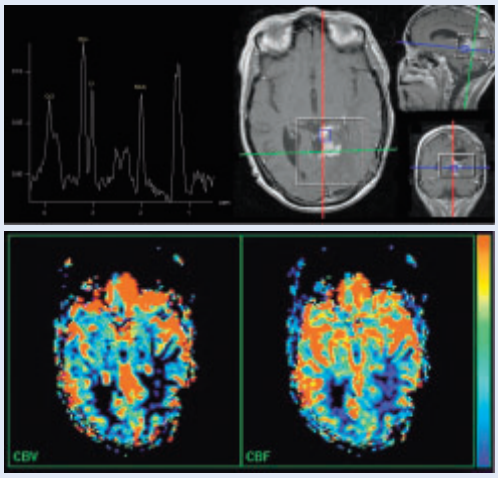


*Choline map.*

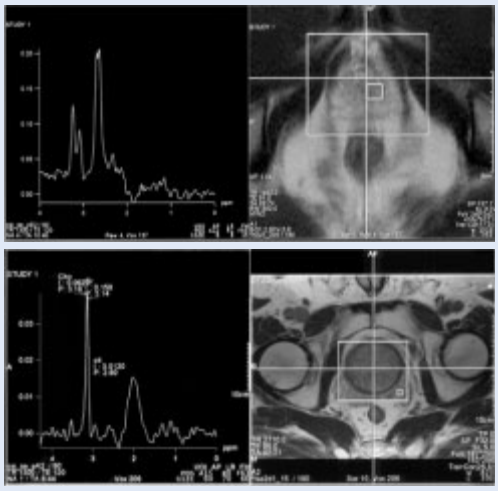
**Low Grade Glioma.**



*Myoinositol map.*




*Treated non-small cell lung ca metastasis.*

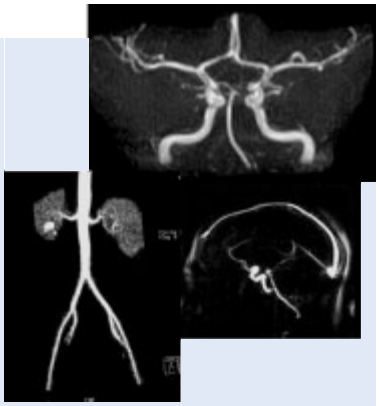


*Normal Prostate.*

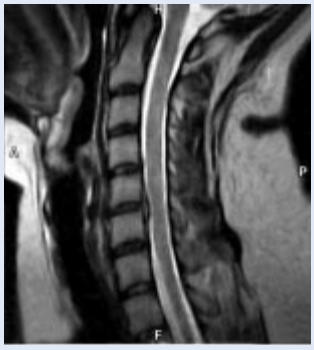
*Prostate Cancer.*


**Dr. Frank Shellock,** University of Southern California, discussed the safety issues with MR and with 3 Tesla systems in particular, providing specific information on acoustic noise, RF fields, RF heating, MR incidents and accidents. He stressed the importance of screening in MR environment. Dr. Shellock also detailed several examples of implants and devices, ranging from neurostimulators and orthopedic implants to pacemakers. "Ensure you obtain information about the implants and devices before commencing the exams" was his important advice to all users, offering an example of the difference between short bore and long bore 3 Tesla systems in terms of safety: an implant which is deemed safe for long bore systems, need not necessarily be safe for short bore. He concluded with the topic of post-operative patient handling.

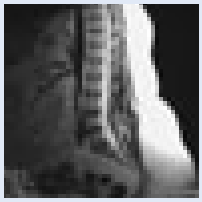

**James Stupino BS, RT R,** from Valley Advanced Imaging, talked about improving the clinical throughput in Open Systems. His talk included topics such as organizing the facility, patient preparation, imaging techniques, coil selection and positioning, sedation. He also offered the audience useful tips for obtaining the best image quality especially with heavy patients and in the area of cervical spine imaging.



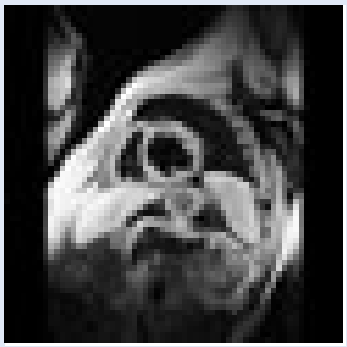
*MRA with MAGNETOM Concerto.*



*295 lbs male.*



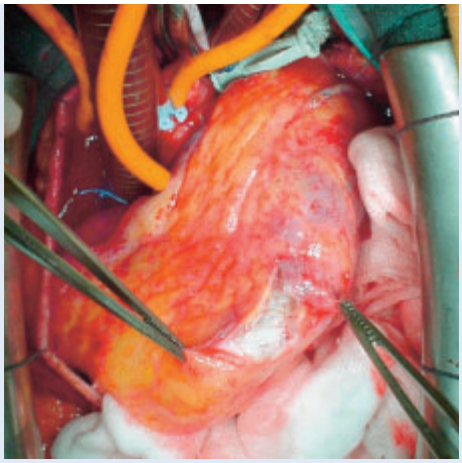
*Patient weight 360 lbs.*

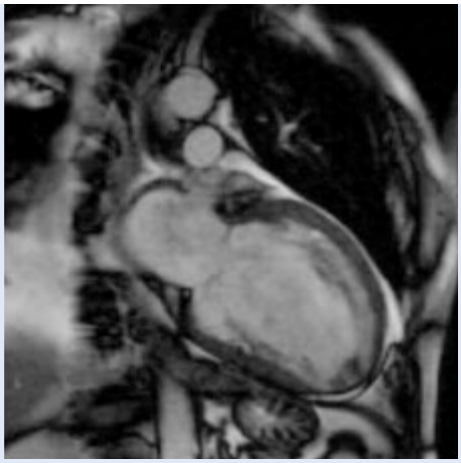


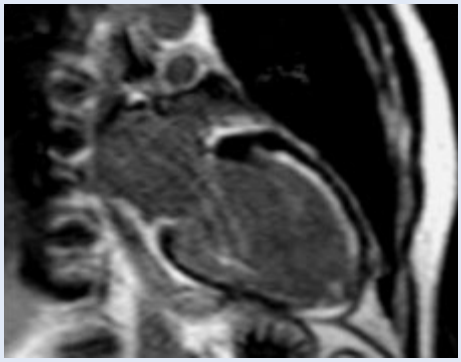
*Cardiac MR with MAGNETOM Concerto.*


**Prof. Vincent Dor,** a world-renowned cardiothoracic surgeon, shared his experience with MAGNETOM Sonata system at the imaging center in Monaco Cardio Thoracic Center, which is dedicated solely to cardiovascular patients. He began his talk by showing the advantages of CMR over conventional angiography and echocardiography. His case reports from the clinic showed the clear benefits of CMR in daily practice for even surgical patients, especially the use of late enhancement viability* imaging and functional cine visualization of the heart for surgical decisions. He believed that CMR could have a revolutionary effect in the follow-up of infarct patients with today's results of left ventricular function evaluation with cine MR and late enhancement viability scanning, providing the exact area of scar formation.

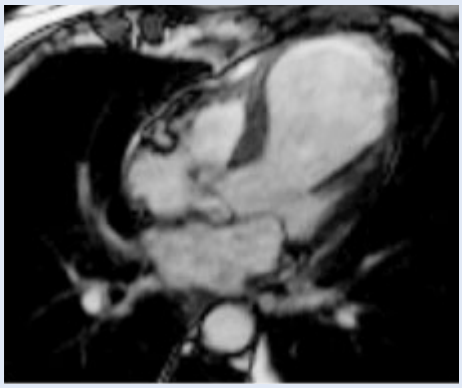
** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

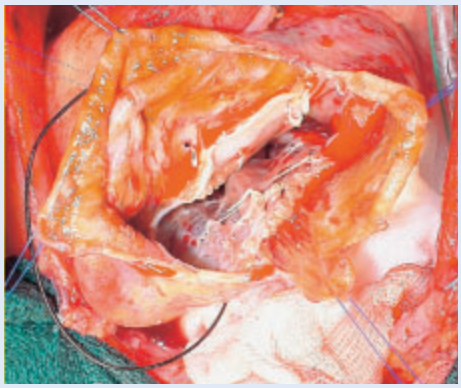


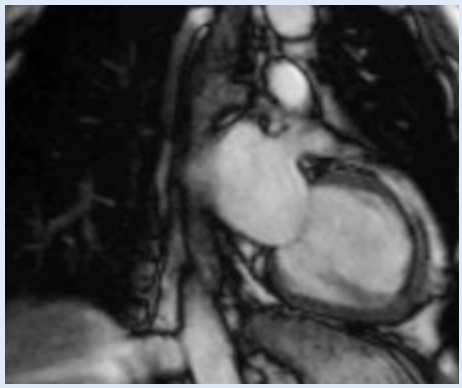


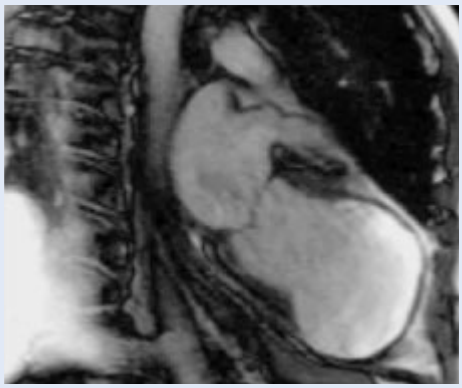


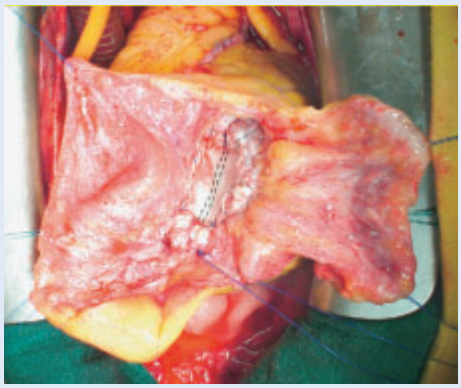
*Sub Endocardial Infarct.*

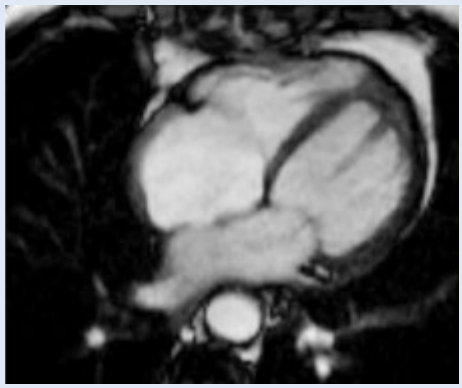








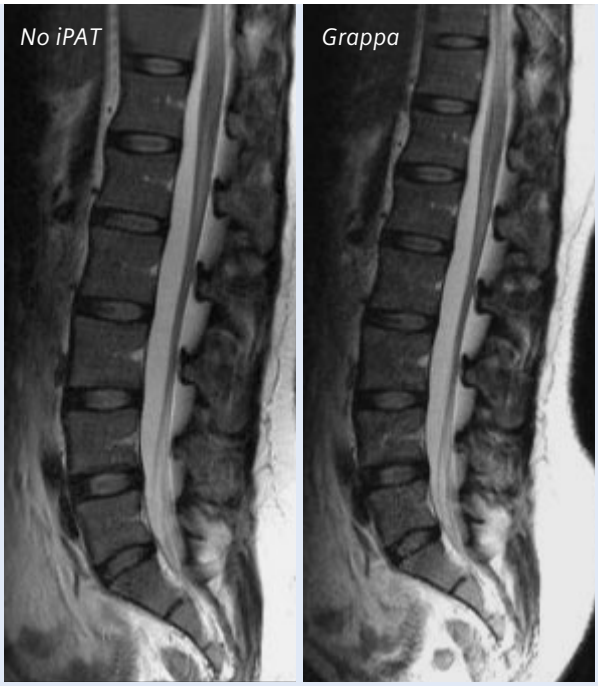




*EDVI: 121 ml/m²*
*ESVI: 95 ml/m²*
*LVEF: 22 %*

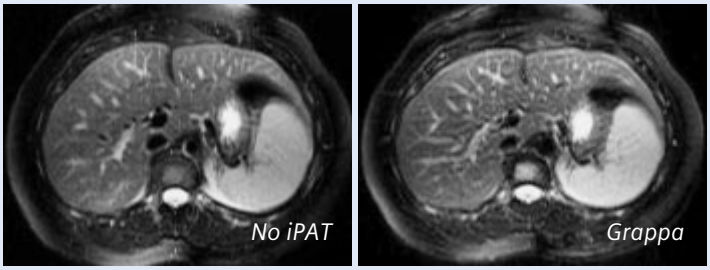
*EDVI: 54 ml/m²*
*ESVI: 25 ml/m²*
*LVEF: 53 %*

**Margaret King (RT R MR)** gave a comprehensive talk about increasing the throughput in high field systems, starting with the 'user interface' and then moving to *syngo* specific improvements like image stamps, inline movie, inline subtraction and off-line reconstruction. She emphasized the importance of IPA™, saying that it had increased remarkably the number of patients that can be scanned in one day. Phoenix was Margaret's favorite: it allowed the extraction of sequence details from the images, thereby enabling exact replication of sequences and protocols. She stated that iPAT was another useful application either for faster imaging or higher resolution in the same imaging time. 2D PACE was another very important improvement in the new *syngo* based systems, improving the daily clinical MR in abdomen imaging.




*Sagittal T2*
*3:12 minutes.*

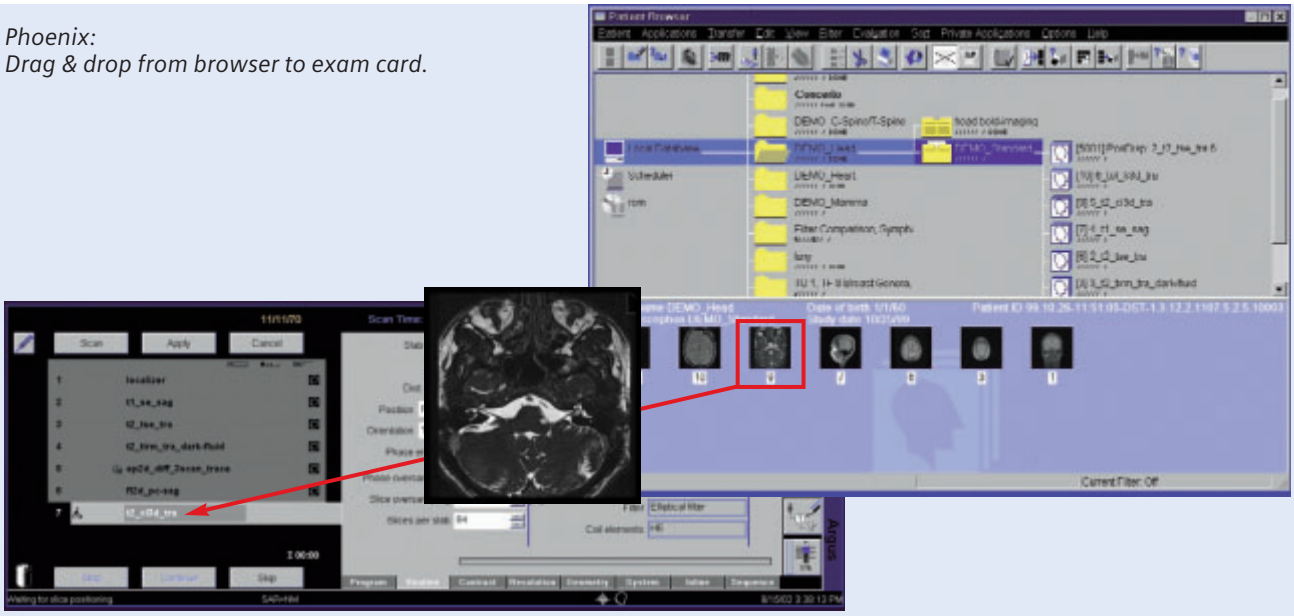
*PAT factor 2*
*Sagittal T2*
*1:48 minutes.*




*25 sec* *14 sec*

**Clearly the "Imaging of the future!"**

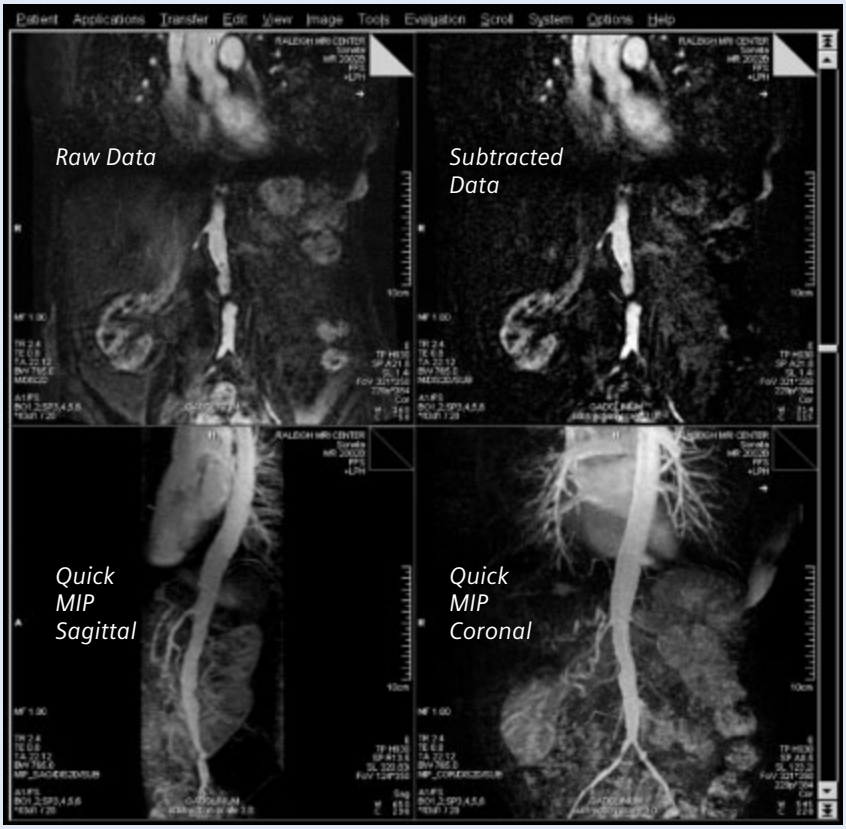
*Phoenix:*
*Drag & drop from browser to exam card.*



## Phoenix: Revolutionary way to exchange MR data

- Images available through Internet, CD or floppy.
- Easy protocol exchange (gradient strength not an issue).
- Improves study reproducibility for follow-up and research.
- Supports multi-center protocol standardization.
- Helps to establish new applications.

## Angiography / Inline Subtraction




**Dr. Bernhard Schulte** introduced his clinic as representative of a business model combining the radiologists' and cardiologists' efforts to one common goal. "MR is providing not only morphological but also physiological information which is very important in the evaluation of patients," said Dr. Schulte. He detailed the use of stress MR, viability imaging*, cine MR for wall motion analysis and ejection fraction calculation, and said that the use of these methods with MR is expanding the services of cardiologists. Radiologists' expertise in imaging and cardiologists' expertise in cardiology should be combined for expanding the use of cardiac MR rather than getting involved in turf battles. Köln Cardiac MR Center is a center for collaboration where there is one CT and 2 MR units to which more than 80 private cardiologists are sending their patients for further evaluation. There are also educational courses in the center available to referring cardiologists in the Köln Cardiac Center.

*Köln/Cologne*

*Kardio MR/CT Team Cologne*


- Radiologic-cardiologic joint effort.
- One of the very first radiologic-cardiologic collaborative MR Centers in Germany specifically focused on cardiovascular MRI.
- Development and clinical application of MR imaging to the cardiovascular system.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

## Milestones in the formation of Kardio MR Köln/Bonn

**Spring 2000**

8 cardiologists in private practice decided to be involved in Cardiac MRI.

**2000**

Formal talks culminated in a cooperation between this group of cardiologists and the Department of Radiology.

**Mid 2000**

Installation of Multislice CT and Cardiac MRI units.

Clinical fellowship of radiologists in other specialized Departments of Cardiology (Dortmund, Essen, Bad Nauheim).

**Autumn 2003**

Since 3 years they have been developing a great working relationship with more than 80 privat cardiologists and 3 Departments of Cardiology in other hospitals.

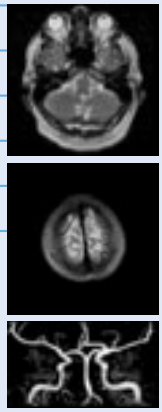

**Dr. Stefan Ruehm,** from Essen University, emphasized the importance of prevention in medicine. He said MR was very suitable for early diagnostic purposes as it was non-invasive, without any x-ray and known side effects and was highly accurate. He provided the protocols and sequence details for the examination of the whole body including neurovascular examination, cardiac examination, thoracic examination, MR colonography and metastasis detection. His final comment was succinct and clear: "Multi-organ screening with MR appears feasible".

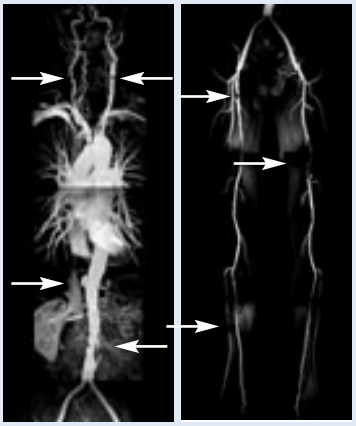
**60 Minute MR Prevention Protocol**

| | |
|---|---|
| Cerebral morphology (ischemia imaging) | 10 min |
| Arterial vascular tree from head to ankle | 10 min |
| Cardiac morphology and function / lungs | 20 min |
| Virtual endoscopy of the colon for polyps and colorectal cancer | 20 min |
| | **60 min** |

**Cerebrovascular MRI**

- T1-w SE
- T2-w TSE
- FLAIR
- 3D ToF
- No i.v. contrast
- Exam time 10 min



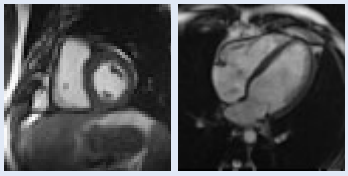


*67 year old male: systemic manifestation of atherosclerosis.*

*WB MRA; TA: 72 sec.*

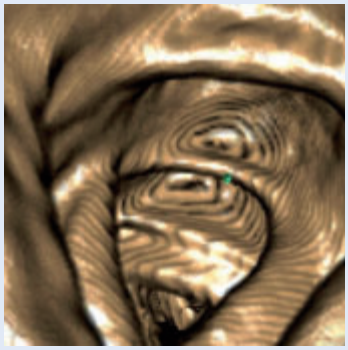
### Cardiac MRI

- i.v. contrast of MRA used for late enhancement*
- CINE short and long axes
- Exam time 20 min



### MR-Colonography

- Rectal enema: 2.500 ml water
- 0.1 mmol / kg BW Gd-BOPTA
- 3D VIBE – delay 75 sec
- Exam time 10 min

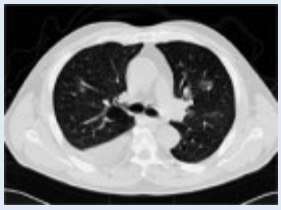


### Visualization of Metastases

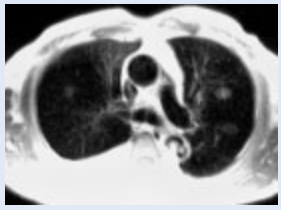
- Implemention of whole-body MRI examination for detection / staging of metastases.
- Whole body MRI using 3D-VIBE.
- Fast & nearly isotropic resolution.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

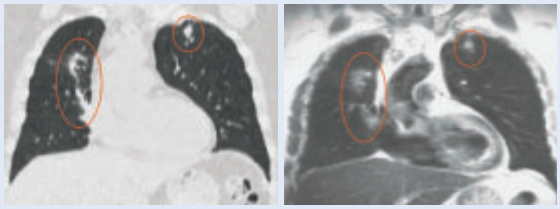
**Dr. Stefan Schoenberg,** from Ludwig-Maximilians-University of Munich, Germany, gave an excellent summary of iPAT and its clinical use ranging from head to toe. The details of this topic can be seen in the article from him on pages 6-20.



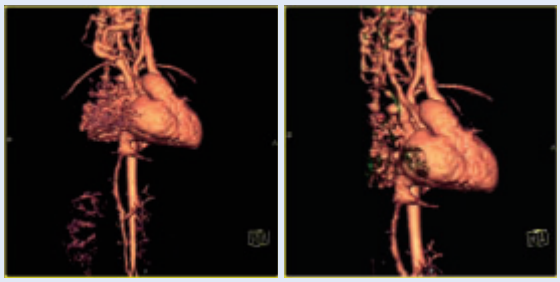
*HR-CT*



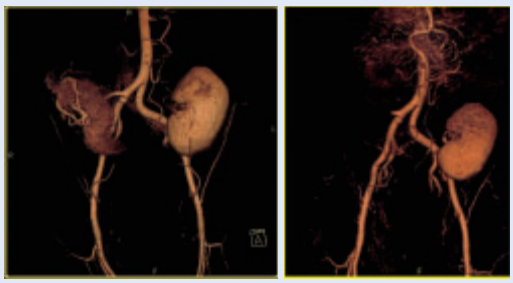
*MRI*



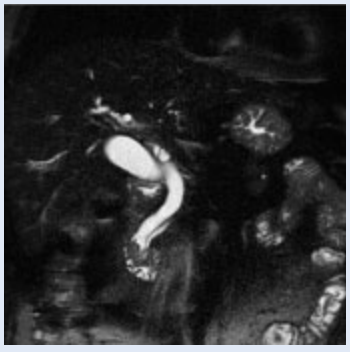
*Atypical pneumonia: coronal images.*



*7 month-old premature newborn: MRA with GRAPPA, 1.0x0.8x1.0 mm isotropic spatial resolution, 8 seconds acquisition time.*



*Value of isotropic spatial resolution.*

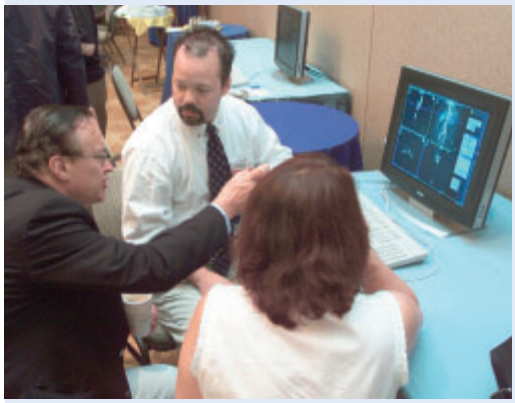


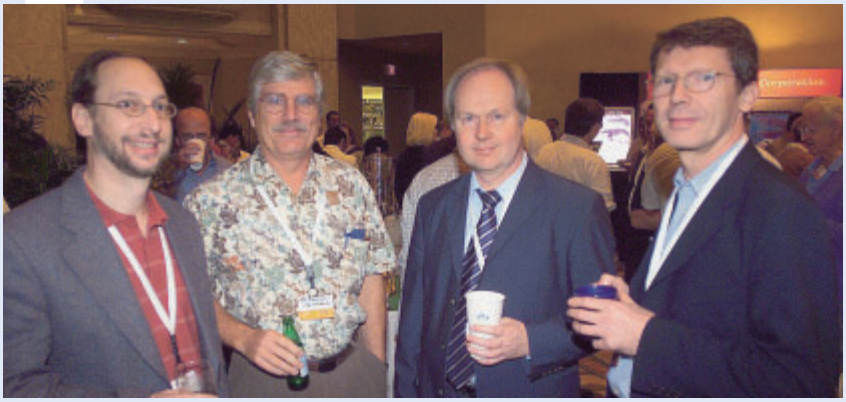
*Choledocholithiasis DDX endoluminal tumor.*

The first day ended with a talk by **Scott McPherson VP,** from a private out-patient center called "Open System Imaging". This was a very interesting talk about the MR market and current dynamics. He said that the out-patient market was totally different from the in-patient one and his observation was that market-oriented centers did well compared to only marketing-oriented ones, which had disappeared from the market. The other topics he covered were changes occurring in referral patterns and decreasing reimbursement. His interesting observation was that the market was reaching maturity and MRI was becoming a commodity service. "Profit lowering is a reality in the market today" he said. He defined today's market as more or less a "high-field market". He stressed the importance of the quality perception of the customer. Price leadership, he stated, was becoming a major issue in the market.

# Coffee Break MAGNETOM World Summit


The coffee breaks between sessions were good opportunities for participants to visit the demo workstations and discuss the new developments by Siemens MR.





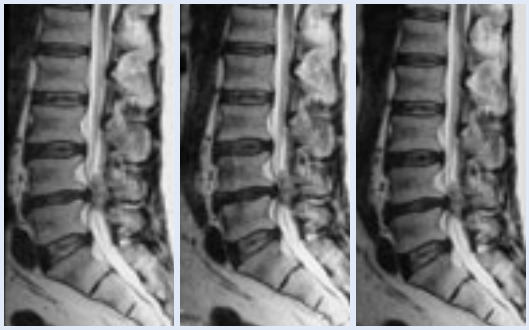

Devices Corporation

# 2nd Annual MAGNETOM World Summit September 17-19, 2003

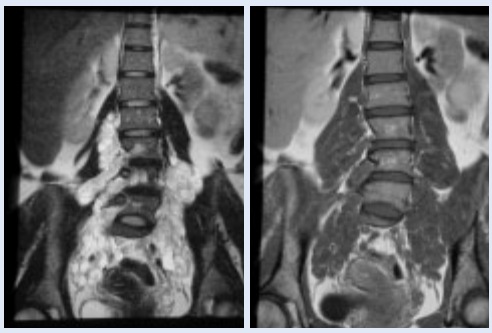


# 18th Thursday – Evening

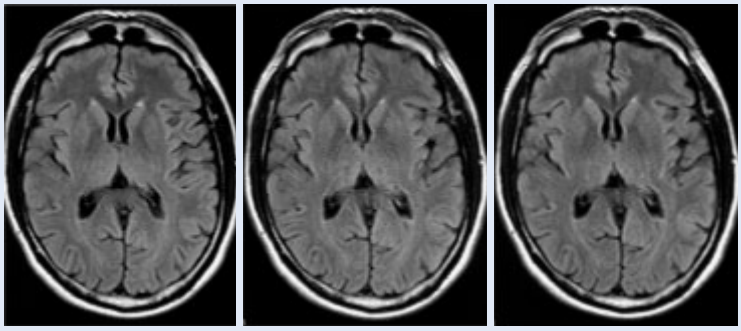
**Dr. Pierre Brugieres,** from Henri Mondor Hospital, talked about the use of iPAT in clinical neuro-radiology. His presentation included examples ranging from clinical neuro to advanced neuro applications. He presented results with both techniques of mSENSE & GRAPPA showing the advantages, disadvantages and artifacts related with both techniques. His talk ended with the wish for more coil elements, channels and increased S/N ratio.



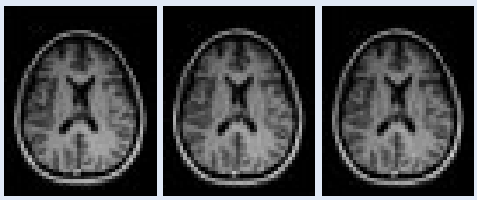
*Spinal canal imaging:*
*no PAT* *mSENSE* *GRAPPA*



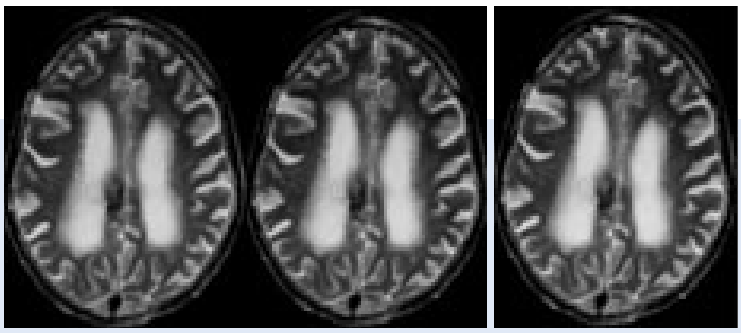
*Spinal imaging.*



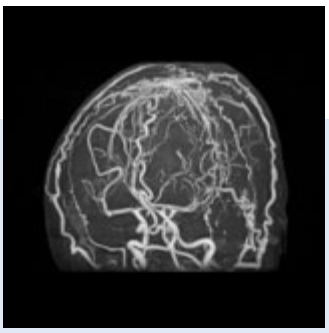
*Turbo-FLAIR imaging:*
*No PAT* *mSENSE* *GRAPPA*



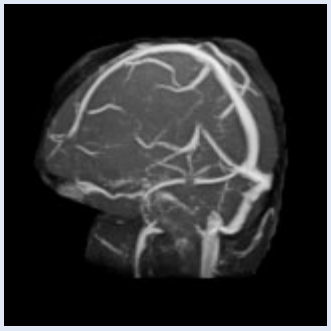
*T1w-gradient Echo imaging:*
*No PAT* *mSENSE* *GRAPPA*
*TA = 1'18* *TA = 0'55* *TA = 0'55*



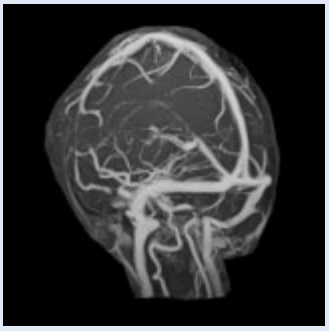
*TR = 4090 ms, TE = 101 ms, nex = 1, 20 slices, T2-TSE imaging:*
*No PAT* *mSENSE* *GRAPPA*
*TA = 0'55* *TA: 0'34* *TA: 0'34*



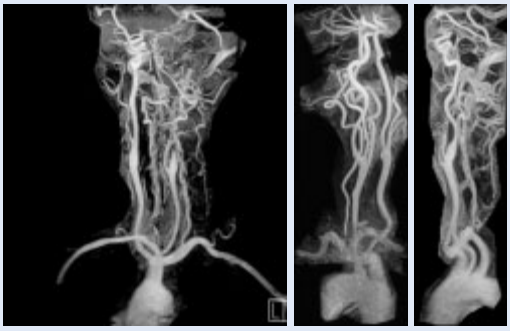
*ToF of the circle of Willis*
*TA: 7'35*
*GRAPPA: PAT factor 2.*



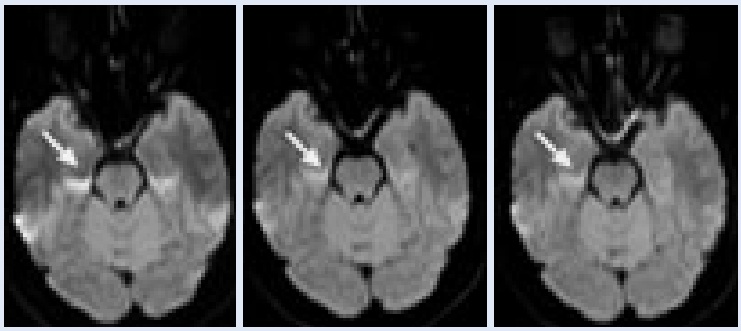
*2D ToF Venous MR Angiography*
*TA: 3'30*
*GRAPPA: PAT factor 2.*



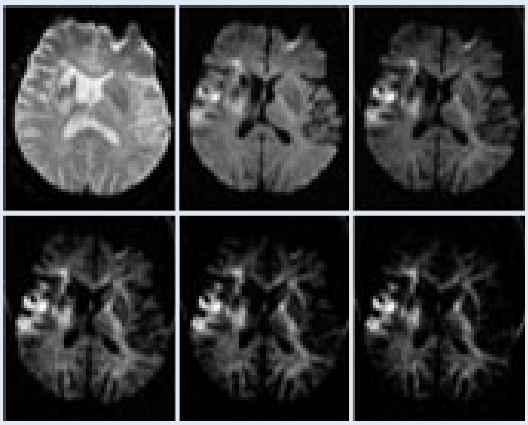
*3D Gd Venous MR Angiography*
*3D MPRAGE (sl. thick. = 1.6 mm)*
*GRAPPA (PAT factor 2), water excitation 10 cc DOTA-Gd, TA = 1'35.*



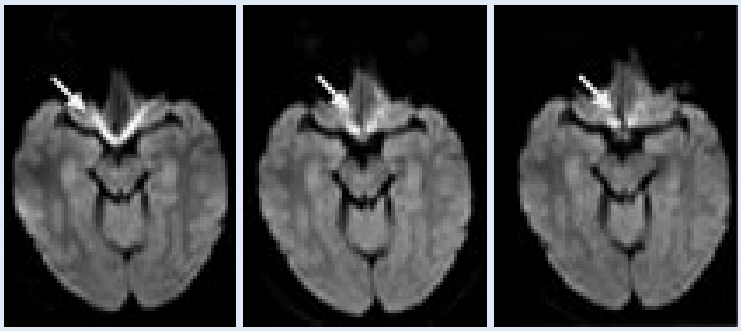
*3D-Gd-enhanced MRA.*



*Diffusion weighted imaging:*
*No PAT* *mSENSE* *GRAPPA*

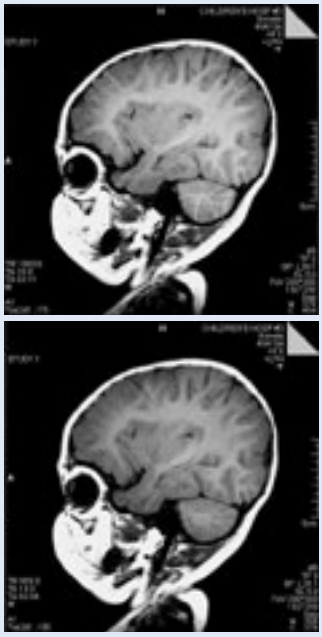


*DWI with high b-factor values:*
*Stroke imaging.*



*Diffusion weighted imaging:*
*No PAT* *mSENSE* *GRAPPA*

**Christine Harris, RT R MR,** from the Children's Hospital of Philadelphia, introduced the clinic where she is working – one of the biggest referral centers in pediatrics and pediatric imaging in the world. The clinic performs about 15,000 MR examinations per year. Her talk focused on optimizing the clinical throughput in a busy practice. She introduced the challenges of pediatric imaging ranging from sedation to examination room surroundings, scanning techniques, protocols and application tips.



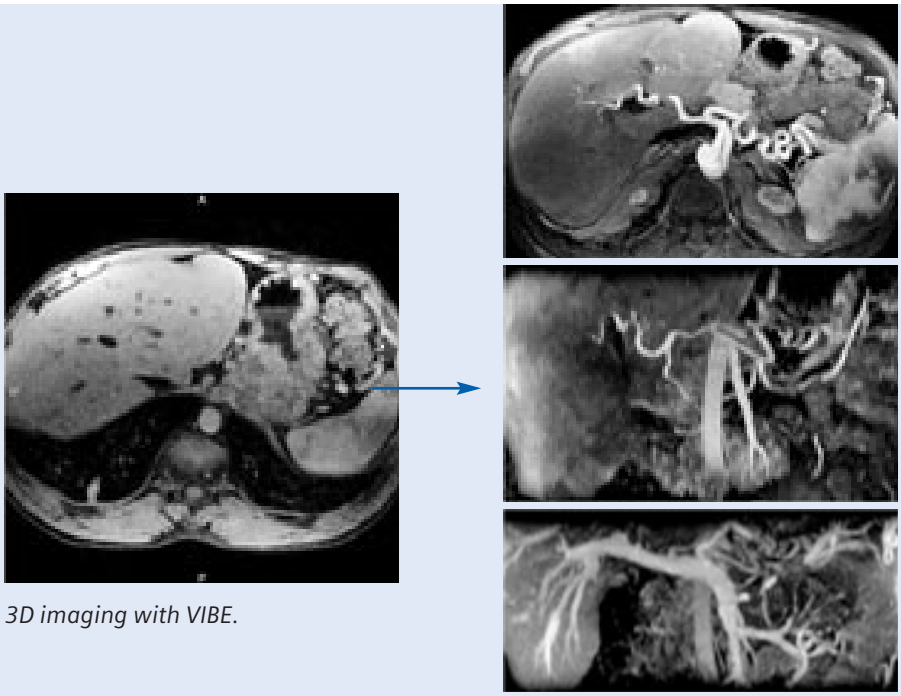
*Improvement of gray/white matter contrast*
*1000 TR vs. 650 TR.*

### Neuro Imaging Protocol setup

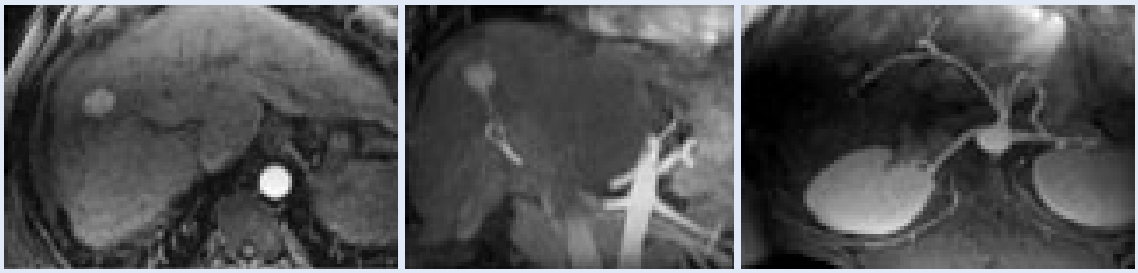
- Routine brain under 6 months
- Routine brain 6 months to 1 year
- Routine brain 1 year to 2 years
- Routine brain 2 year and up
  - Scout
  - Basic brain
  - Basic brain post contrast
  - Midline infratentorial
  - Pathology
  - Seizure
  - Seizure post contrast
  - Trauma/Stroke
  - Developmental delay
  - Orbits
  - Orbits post contrast

*Sag_T1*
*Axial_T2*
*Axial_FLAIR*
*Axial_MT when giving contrast*
*Axial_SE not giving contrast*
*Diffusion*
*Cor_T2*
*Cor_FLAIR*
*Cor_STIR*
*Cor_T2*

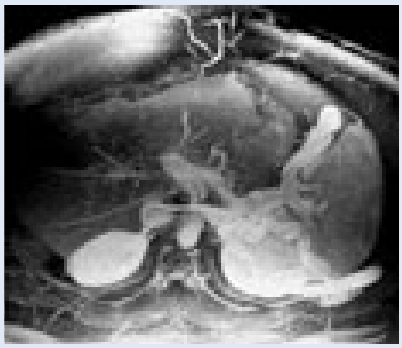

**Dr. Vamsi Narra,** from Mallinckrodt Institute of Radiology, concentrated on 3D imaging of the liver, and shared his clinical experience with other users. 3D imaging with VIBE provides angiography information and parenchymal information simultaneously with thin slices and no slice gap. According to Dr. Narra, it was more advantageous to use 3D than 2D. He provided technical details of the VIBE sequence. He showed the parameters he preferred with this sequence. He also introduced the workflow in his clinic regarding post-processing, distribution of images with PACS. 3D biliary anatomy evaluation after contrast injection was an interesting application that showed impressive results, as he demonstrated. He stressed the parallel imaging iPAT, which he said was similar to multi-slice CT and possibly the future for MR.



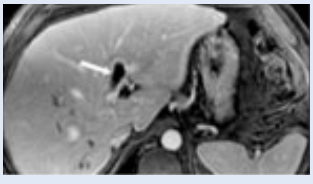
*3D imaging with VIBE.*

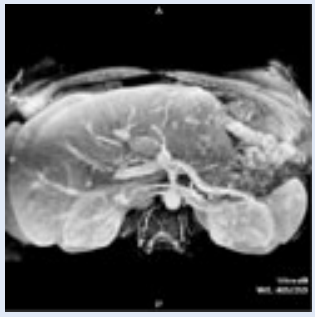


*Hepatocellular carcinoma evaluation with VIBE.*



*Splenorenal shunt.*





*Portal vein thrombosis.*

**Dr. Scott Pereles,** from Northwestern University, talked about MR Angiography in clinical practice. He said that MRA was quite a mature application for most anatomical areas. He drew the attention of the audience to the advantages of MAGNETOM systems, especially Sonata, with the lowest TRs and TEs in the industry. He gave very useful application tips for state of the art MRA covering all anatomical areas of the body including the peripheral MRA examination with moving table. He also showed different imaging techniques like freeze frame MRA and advanced post-processing techniques like volume rendering. He added that iPAT brought significant advantages to MRA.

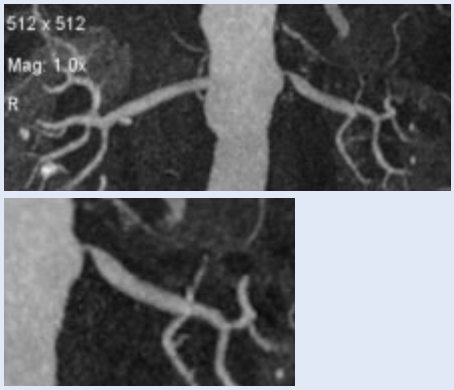
**Dr. Charles Ho,** from National Orthopedic Imaging Associates, shared his experience in MR orthopedics imaging with the audience. He focused especially on elbow imaging.

**Dr. Frank Miller,** from Northwestern University, talked about 2D liver imaging. "Abdominal MR should be short and breath-hold is the way to go," said Dr. Miller. He prefers the one-stop approach in upper abdomen imaging to detect and analyze the lesion in the liver and evaluate the biliary system. He introduced the abdominal imaging protocols in his clinic and explained the use of different sequences for different applications and for different pathologies. SHARP is one of their favorite sequences for liver imaging – a 2D fat-sat gradient echo with some modifications. He provided the audience with clinical examples in abdomen imaging.

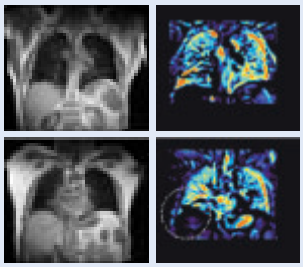

**Dr. Diego Martin,** from West Virginia University, talked about improvements in MR imaging of the bowel. He observed that imaging of the bowel, which had previously been thought to be unsuitable for MR, was being used with increasing frequency. He talked about dark and bright lumen imaging techniques and showed some experimental results using different techniques and their impact in imaging. He stated that water and TrueFISP combination provided the best results in these experiments, with VIBE also having other advantages. He also shared his clinical experience in colon MR imaging, from patient preparation to the examination details.

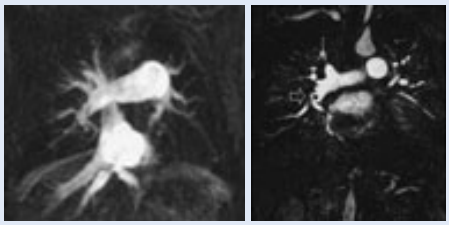
**Dr. Guenter Layer,** from Ludwigshafen Clinic, showed extremely impressive results form his center, where there is good cooperation between the radiology and gastroenterology departments. The MR colonoscopy topic and the indications results from Ludwigshafen Clinic can be seen in this issue of Flash on pages 110-115. Dr. Layer's interesting view was that MR would become the screening method of choice in the future and conventional colonoscopy and sigmoidoscopy would be kept only for therapeutic reasons.


In his second talk in two days, **Dr. Schoenberg** discussed the burden of renovascular diseases in the community and why MR could be useful in alleviating this problem. He believed that we should move from pure morphology to function in evaluation of renovascular diseases. He first talked about flow evaluation of the renal artery pathologies, then moved to the topic of renal perfusion – the perfusion of the kidneys to be able to get functional information related with the renovascular pathologies. He proved his experience with quantitative perfusion measurements. The second part of his talk was dedicated to lung perfusion measurements, the clinical need for this evaluation technique and some clinical examples, and he stressed the value of this application in particularly thromboembolic diseases.

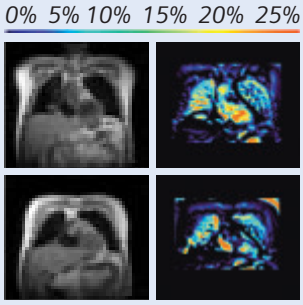



*Voxel size: 3.4x0.7 mm³ with iPAT GRAPPA + MAGNETOM Sonata.*





*Chronic thromboembolic disease: MR perfusion.*




*$O_2$ imaging: Ventilation defect.*

After Dr. Schoenberg's talk, Dr. Bengi from MR Marketing thanked all the speakers and attendees for making the 2nd MAGNETOM World Summit such a rich experience. He said that the three communication platforms for this global network – the Internet (with Phoenix), MAGNETOM World meetings and Flash Magazine – would continue to develop and grow richer with more contributions from the MAGNETOM World. He reminded everybody to contribute to this biggest community in the medical imaging world. "See you all next year in Europe at the 3rd MAGNETOM World Summit" he ended, as a reminder to the audience to note their diaries for another scientific meeting full of information, advice, fun and excitement in 2004.

# Crues-Kressel Award

This year the Crues-Kressel Award has been bestowed upon Greg Brown, Senior Radiographer MR, Royal Adelaide Hospital. The Crues-Kressel Award is conferred by the SMRT (the MR technologists Section) of the International Society for Magnetic Resonance in Medicine (ISMRM). The citation reads "for outstanding contributions to the education of Magnetic Resonance Technologists".

It is the only SMRT award decided by the membership. A ballot is held citing two or three candidates approved by the SMRT policy board, and the award is given to the ballot winner only if more than 50% of the SMRT membership vote. In a real sense it is an award made by one's professional peers.

2003 is the 11th time the award has been made in the past 13 years. Previous Crues-Kressel awardees include educators and safety experts Dr. Emanuel Kanal, and Dr. Frank Shellock, Christine Harris (currently an active MAGNETOM World participant in paediatric imaging), Candi Roth, Kelly Barron (instigator of the SMRT Home Studies Program), and Anne Sawyer-Glover of Stanford University California.

Greg is the first non-U.S. recipient of the Crues-Kressel award, gaining recognition for his local and SMRT related work, but probably most particularly for his global presence through the Adelaide MR web site (www.users.on.net/vision) and several years of active participation in the MRI Technologists' list initiated from Duke University by Richard Helsper, and now managed by the SMRT office.

## Greg Brown:

Greg's passion for MRI has always been matched by the desire to share information as well as keeping Australian MR Radiographers connected to the world scene. He believes strongly that well educated MR radiographers play a pivotal role in delivery of quality MR services for the patient. They create the link between the physics and engineering of scanner designs with the questions of radiologists and clinicians to provide answers for the patients, at the same time as managing the patients' experience of the examination.

For several years he distributed a handmade MR newsletter to about thirty sites around the region. Since meeting Michael Kean in 1991, Greg has participated as faculty at many Australian MR user meetings. He assisted with organisation of the 1998 ISMRM/SMRT meetings in Sydney under the chair of Dr .Carolyn Mountford, wrote course material for post graduate students at Sydney University and Charles Sturt University, and lectured at the University of South Australia. Greg continues to work as an on-line tutor with the RMIT.

Greg has a long close association with Siemens MRI beginning in 1986 with a factory visit after the Royal Adelaide Hospital's decision to purchase a 1Tesla MAGNETOM GBS2 system. Getting the most out of these early systems relied on developing close informal contacts with the designers and engineers in Erlangen and around the Siemens MR community, and Greg attributes much of his perspective on current MR to these initial contacts. In 1997, after the R.A.H. decided on a Siemens MAGNETOM Vision, Greg returned to Erlangen to undertake the PARGEN Pulse programming course, trying to gain a better understanding of how the scanners work.

Using the MAGNETOM Vision, Greg emphasised 3D T1 imaging with MP-RAGE, adopted CE-MRA after exploring the role of stepping 2D ToF MRA, undertook cardiac MR exams in the late 90's, and in the past few years introduced regular MR Spectroscopy examinations of brain tumors. His current interest is in rolling out a technique, developed by the University of Western Australia and possible on all Siemens 1.5 T scanners, to monitor and better manage iron overload, improving the quality of life for Thallassaemia patients, and sufferers of Genetic Haemochromatosis.

Greg hopes to continue in MRI, sharing his perspective and learning from the Australian and international community of MR radiographers.

Greg now commences a 3 year term on the Policy Board of the SMRT, and is the Chair of the Publications committee as well as working on the programme for the next SMRT meeting in Kyoto, Japan, May 15-21 2004.

# R2-HIC: A Practical Method for Measuring Liver Iron Levels*

Greg Brown

Senior Radiographer MR
Royal Adelaide Hospital


## Introduction

The Royal Adelaide Hospital has added quantitative liver iron measurement into its Radiology services to provide critical information for clinicians managing iron overload (haemochromatosis) patients. The R2-MRI Hepatic Iron Concentration method was developed by the Biophysics Research team of the University of Western Australia (Prof. Dr. Tim St. Pierre, Dr. Wanida Chua-anusorn and Mr. Paul Clark) [1] with the assistance of Radiologist Dr. Jay Ives and Radiographer Erin Robins of SKG Radiology, Perth Western Australia.

By combining prescribed techniques, a simple calibration scan, and central data analysis, R2-HIC delivers a precise liver iron assay based on extensive validation work. This method is machine independent and reproducible without local validation experiments, offering a unique opportunity to introduce an important diagnostic test quickly and globally.

## Iron overload

Iron overload is a serious condition, affecting patients all over the world. Untreated, it will cause cardiac failure, liver failure, diabetes, or hepatocellular carcinoma. [2]

Genetic haemochromatosis (GH or HH) is an autosomal recessive genetic condition affecting about four people in every thousand of U.K. or Northern European ancestry and carried by one in ten [3], making it the most common genetic disorder in the Australian community [4]. Patients usually present later in life displaying liver failure, cirrhosis, diabetes, hepato-cellular carcinoma, or cardiac failure, which are the consequences of prolonged iron accumulation in the liver, endocrine systems and heart. It is increasingly recognised that GH is under-diagnosed, so regular testing of iron storage levels is recommended for all siblings with genetic testing if high results are found. Treatment regimes of venesection (controlled bleeding or donation) will minimise iron accumulation and avoid serious complications.

Acquired haemochromatosis (AH) affects people undergoing repeated transfusions for inherited anaemias such as beta-thallasaemia, and sickle cell. These conditions affect people of African and Mediterranean descent, and while rare, a recent W.H.O. review predicted over 3.5 million new sufferers will be born each year in Africa, Southern Europe, the Middle East, India, South East Asia, and Southern China. The diseases are also present in countries with significant ethnic communities from these pan-equatorial regions. Managing patients with acquired haemochromatosis is more complex and expensive, relying on iron chelation drugs to remove excess iron form the body.

In both groups, accurate management depends heavily on accurate quantification of iron concentration in the liver (HIC), to monitor the total body iron burden. A single measure of HIC will not ensure effective clinical management. These patients benefit from a method that will frequently and accurately measure HIC, without complications [5].

Liver biopsy is the common method of measuring HIC. The procedure is invasive and subject to significant procedural, performance, and sampling errors. While the results are reliable, about one in five procedures yield an inadequate tissue sample [6]. Liver cirrhosis, commonly associated with chronic iron overload, will further decrease the accuracy of liver biopsy because of the chance of sampling fibrotic tissue regions [7]. Liver biopsy on children usually requires anaesthetics and admission, introducing more complications and expense.

Many clinical centres accept these performance limitations, and perform biopsy annually. Others use biopsy less frequently to reduce morbidity or expense, relying on combinations of the less reliable serum ferritin test, iron loading calculations, and clinical signs.

## MR assessment of liver iron concentration

MR is particularly well suited to detecting tissue iron concentration. Iron is stored in the liver as two paramagnetic proteins, ferritin and haemosiderin [8] [9]. These compounds shorten T1 and T2 in proportion to the local concentration. Many groups use the signal intensity ratios (SIR), of liver and skeletal muscle in a simple single sequence protocol [10] [11] to assess the level of tissue iron. Others use multiple sequences, altering only the echo time, then use the signal intensity values to plot the signal decay curve to find a value for T2. Similar approaches have been made looking at T2* decay.

Iron loaded tissues exhibit T2 values of around 5 msec. resulting in signal

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

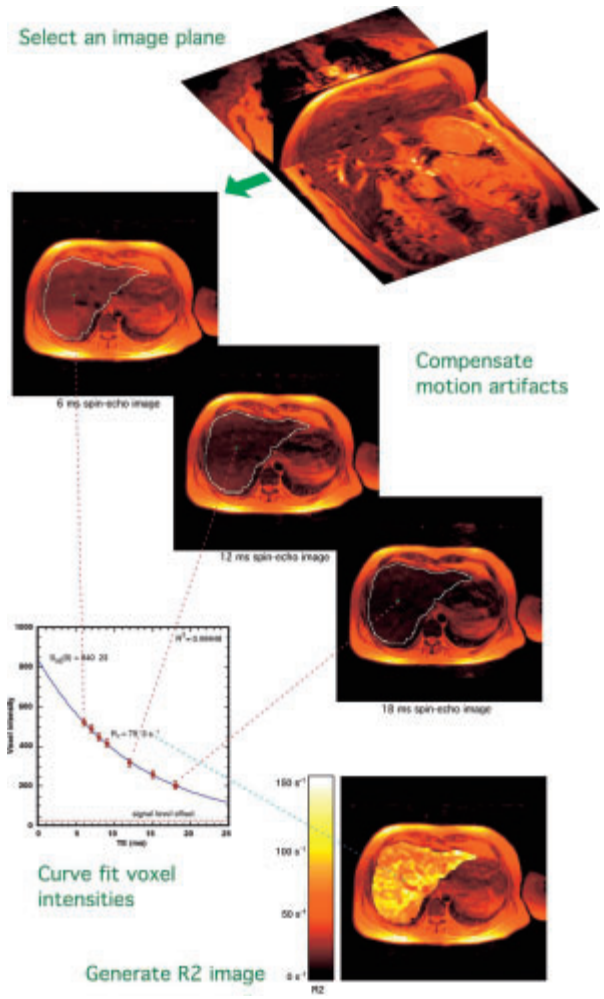



Figure 1
*Steps in R2-MRI Image Analysis.*

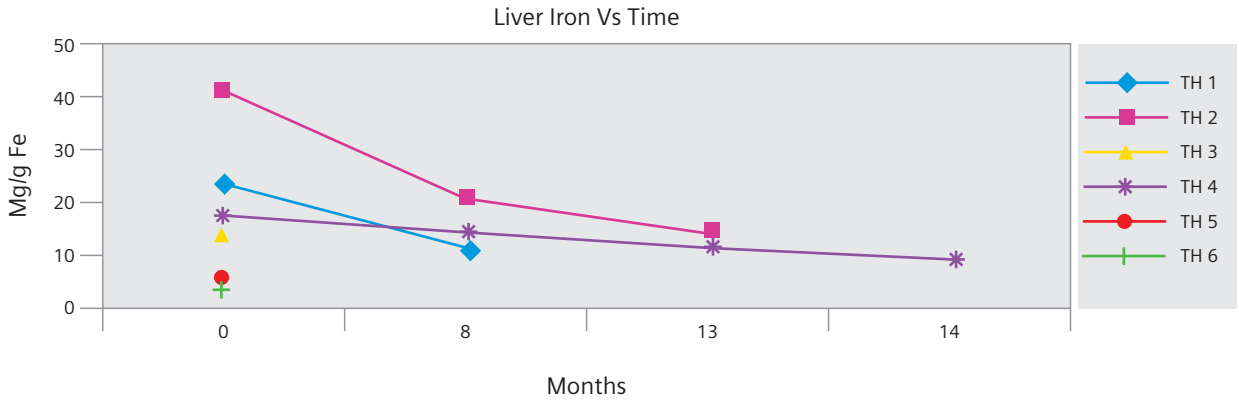



Figure 2

levels very close to noise floors. This emphasises the need to collect data early and close in the echo time domain, and on the development of sophisticated mathematical algorithms to perform accurate curve fitting in the presence of low SNR.

Relaxometry and ratio methods have delivered reliable assays of liver iron in their original institutions but the work is not propagated because of the need for time-consuming verification studies to calibrate machine specific techniques and their results with objective liver iron assays.

## R2-MRI method

Following some basic instruction and calibration using a custom phantom, the method can be performed on any MAGNETOM Vision, Symphony or Sonata scanners using standard image sequences and the CP body array coil.

Six spin echo acquisitions (TR 2500 msec. TE 6,7,8,9,12 &15 msec), are obtained with fixed receiver gain factors. 19 axial slices 5 mm thick and 5 mm apart, with typical pixel dimensions of 1.4x1.4 mm cover the whole liver. Close clustering short TE acquisitions maximises SNR, and is necessary to accurately estimate the very short T2 values associated with elevated iron levels. A container of Hartmann's solution or saline is included in the image adjacent to provide a constant signal region, aid in calibration, and assess instrument drift. Total examination time is approximately 35 minutes. R2-MRI can be performed in conjunction with conventional liver MRI as long as contrast agents are not used prior to the R2-MRI measurements.

Scan data is sent via the Internet or CD to the University of Western Australia R2-MRI analysis service for evaluation and reporting. Pixel values are processed to determine the noise floor, and signal offsets, then filtering to address motion artefacts [12] [13] [14]. The values from each echo time are fitted to a bi-exponential decay curve to determine the T2 value for each pixel. The transverse relaxivity value (R2) is simply the inverse of T2; this term is used because R2 is proportional to iron concentration. The R2 values are correlated to iron concentrations using data previously verified against biopsy data [15], yielding a measure of iron concentration in every pixel throughout the liver.

The R2-MRI analysis service reports (usually in digital form via e-mail) to the referring clinician. The report includes the average hepatic iron concentration, the hepatic iron index, and map and histogram of R2 values through the largest part of the liver to demonstrate heterogeneity of iron concentration.

The method is currently used at about 15 scanners through Australia, Asia, Europe and North America, although it could be rolled out to literally thousands of 1.5 Tesla scanners with reliability.

## Clinical experience

Since December 2001, Royal Adelaide Hospital has conducted sixteen R2-HIC examinations for 10 children aged 9 to 16 years. Six have thalassaemia, four exhibit other anaemias requiring repeated infusions. Satisfactory scan data was obtained in 14 examinations without sedation, while two patients (ages 7 & 9) required examination with general anaesthesia. The patients were previously managed with a single liver biopsy, and serial serum ferritin tests. They are now monitored with serial R2-MRI. Their R2-MRI HIC results are plotted in Fig. 2. The initial R2-MRI examinations showed four thalassaemia patients with HIC values higher than the therapeutic target of 7 mg/g. Serial studies show falling HIC levels for three of the elevated group, and one yet to have a follow up scan.

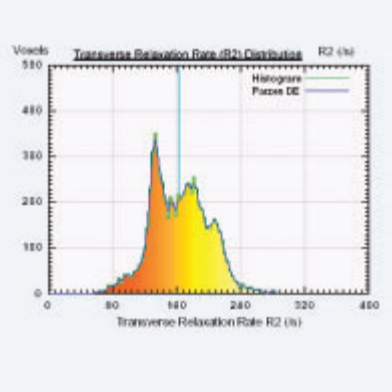
HIC levels were elevated, but acceptable, in the other anaemia patients. R2-MRI will be used annually to monitor their treatment as maintaining low levels of iron loading.

## Summary

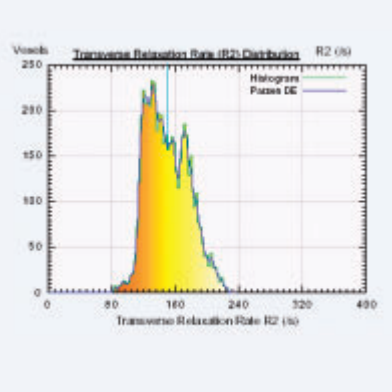
R2-MRI offers a simple, reliable, non-invasive measure of liver iron concentration that can be performed on virtually any Siemens 1.5 T scanner. The centralised data analysis model is well validated, offering immediate clinical utility and avoiding the need for substantial local testing and expertise. The pixel-map approach is not subject to the spatial sampling errors that affect biopsy or large ROI MR approaches.

## Acknowledgments

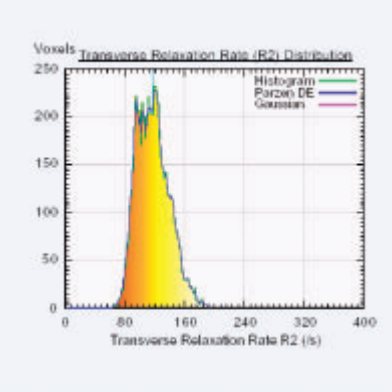
Dr. Wanida Chua-anusorn for comments and encouragement.




*January 2002 HIC 17.2 mg/g dry*




*August 2002 HIC 14.2 mg/g dry*




*March 2003 HIC 8.8 mg/g dry*

**Figure 3** *Draft appearance Thalassaemia. Changing HIC with DFO treatment (patient TH2).*

*Frequency histograms of R2 values in the mid liver slice. The R2 value is proportional to the iron concentration in each voxel. As treatment is optimised, the mean R2 values fall reflecting the progressive reduction in liver iron concentrations. This is matched by an increasingly uniform distribution of R2 values in the slice suggesting the concentration of remaining iron stores become uniform throughout the liver.*

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# Guidelines to Prevent Excessive Heating and Burns

IMRSER

Magnetic resonance (MR) imaging is generally considered to be a relatively safe diagnostic modality. However, the use of radiofrequency coils, physiologic monitors, electronically-activated devices, and external accessories or objects made from conductive materials has caused excessive heating, resulting in burn injuries to patients undergoing MR procedures. Heating of implants and similar devices may also occur in association with MR procedures, but this tends to be problematic primarily for objects made from conductive materials with elongated shapes such as leads, guidewires, and certain types of catheters (e.g. catheters with thermistors or other conducting components).

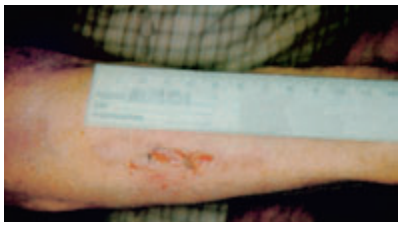

**Figure 1** *Third-degree burn experienced by a patient during an MR procedure. This burn was unrelated to equipment malfunction or the presence of internal or external conductive materials.*

Notably, more than 30 incidents of excessive heating have been reported in patients undergoing MR procedures in the United States that were unrelated to equipment problems or the presence of conductive external or internal implants or materials [review of data files from U.S. Food and Drug Administration, Center for Devices and Radiological Health, Manufacturer and User Facility Device Experience Database, MAUDE, http://www.fda.gov/cdrh/maude.html and U.S. Food and Drug Administration, Center for Devices and Radiological Health, Medical Device Report, (http://www.fda.gov/CDRH/mdrfile.html)]. These incidents included first, second, and third degree burns sustained patients (Fig. 1). In many of these cases, the reports indicated parts of the patients' bodies were in direct contact with body radiofrequency (RF) coils or other RF transmit coils of the MR systems or there were skin-to-skin contact points suspected to be responsible for these injuries.

MR systems require the use of RF pulses to create the MR signal. This RF energy is transmitted readily through free space from the transmit RF coil to the patient. When conducting materials are placed within the RF field, the result may be a concentration of electrical currents sufficient to cause excessive heating and tissue damage. The nature of high frequency electromagnetic fields is such that the energy can be transmitted across open space and through insulators. Therefore, only devices with carefully designed current paths can be made safe for use during MR procedures. Simply insulating conductive material such as wires or leads, or separating it from the patient, may not be sufficient to prevent excessive heating or burns from occurring.

Furthermore, certain geometrical shapes exhibit the phenomenon of "resonance" which increases their propensity to concentrate RF currents. At the operating frequencies of present day MR systems, conducting loops of tens of centimeters in size may create problems and must therefore be avoided, unless high impedance is used to limit RF current. Importantly, even loops that include small gaps separated by insulation may still conduct current.

To prevent patients from experiencing excessive heating and possible burns in association with MR procedures, the following guidelines are recommended:

1 Prepare the patient for the MR procedure by:

**a.** ensuring that there are no unnecessary metallic objects in contact with the patient's skin, such as metallic drug delivery patches, jewelry, necklaces, bracelets and key chains.

**b.** using insulation material, such as appropriate padding, to prevent skin-to-skin contact points and the formation of "closed-loops" from touching body parts.

2 Insulating material (minimum recommended thickness, 1 cm) should be placed between the

patient's skin and the transmit RF coil used for the MR procedure, or alternatively, the RF coil itself should be padded. For example, position the patient so that there is no direct contact between the patient's skin and the body RF coil of the MR system, by having the patient place his/her arms over his/her head or by using elbow pads or foam padding between the patient's tissue and the body RF coil of the MR system. This is especially important for those MR examinations that use the body coil or other large RF coils for transmission of RF energy.

3 Use only electrically conductive devices, equipment, accessories, such as ECG leads and electrodes, and materials that have been thoroughly tested and determined to be safe and compatible for MR procedures.

4 Carefully follow specific MR safety criteria and recommendations for implants made from electrically-conductive materials, such as bone fusion stimulators and neurostimulation systems.

5 Before using electrical equipment, check the integrity of the insulation and/or housing of all components including surface RF coils, monitoring leads, cables, and wires. Preventive maintenance should be practiced routinely for such equipment.

6 Remove all non-essential electrically conductive materials from the MR system (i.e. unused surface RF coils, ECG leads, cables, wires, etc.).

# Institute for Magnetic Resonance Safety, Education and Research

IMRSER

The Institute for Magnetic Resonance Safety, Education, and Research (IMRSER) is an independent, multidisciplinary, professional organization devoted to promoting awareness, understanding, and communication of magnetic resonance (MR) safety issues through education and research.

One of the functions of IMRSER is to develop MRI safety guidelines and to disseminate this information to the MR community in order to help ensure safety for patients, healthcare workers, and other individuals in the MR environment. This is achieved by the Medical, Scientific, and Technology Advisory Board and the Corporate Advisory Board of the IMRSER, utilizing pertinent peer-reviewed, evidence-based literature and by relying on each member's extensive clinical, research, or other appropriate experience.

The Medical, Scientific, and Technology Advisory Board is comprised of recognized leaders in the field of magnetic resonance (MR), including diagnostic radiologists, clinicians, research scientists, physicists, MRI technologists, MR facility managers, and other allied healthcare professionals involved in MR technology and safety. In addition, the Food and Drug Administration has assigned a Federal Liaison to the IMRSER's Medical, Scientific, and Technology Advisory Board. The Corporate Advisory Board is comprised of representatives from the MR industry including MR system manufacturers, contrast agent pharmaceutical companies, RF coil manufacturers, MR accessory vendors, medical product manufacturers, and other related corporate organizations. Significantly, MRI safety guidelines developed by the IMRSER consider and incorporate information provided by the International Society for Magnetic Resonance in Medicine (ISMRM), the American College of Radiology (ACR), the Food and Drug Administration (FDA), the National Electrical Manufacturers Association (NEMA), the Medical Devices Agency (MDA), and the International Electrotechnical Commission (IEC).

The IMRSER's rigorous development and review process for MRI safety guidelines ensures that authoritative and relevant information is produced in a timely manner for rapid dissemination to the MR community.

**It should be noted that the MRI safety guidelines developed by the IMRSER are educational in nature and not specifically intended to be legal standards of care. Accordingly, these MRI safety guidelines may be modified as determined by individual circumstances, currently available resources, differences or changes in technology, and other relevant information.**

7 Keep electrically conductive materials that must remain in the MR system from direct contact with the patient by placing thermal and/or electrical insulation between the conductive material and the patient.

8 Keep electrically conductive materials that must remain within the body RF coil or other transmit RF coil of the MR system from forming conductive loops. Note: The patient's tissue is conductive and may therefore be involved in the formation of a conductive loop, which can be circular, U-shaped, or S-shaped.

9 Position electrically conductive materials to prevent "cross points", which occur, for example, at the point where a cable crosses another cable, where a cable loops across itself, or where a cable touches either the patient or the sides of the transmit RF coil more than once. Notably, even the close proximity of conductive materials with each other should be avoided because some cables and RF coils can capacitively-couple (without any contact or crossover) when placed close together.

10 Position electrically conductive materials to exit down the center of the MR system, i.e. not along the side of the MR system or close to the body RF coil or other transmit RF coil.

11 Do not position electrically conductive materials across an external metallic prosthesis, e.g. external fixation device, cervical fixation device or similar device that is in direct contact with the patient.

12 Allow only properly trained individuals to operate devices such as monitoring equipment in the MR environment.

13 Follow all manufacturer instructions for the proper operation and maintenance of physiologic monitoring or other similar electronic equipment intended for use during MR procedures.

14 Electrical devices that do not appear to be operating properly during the MR procedure should be removed from the patient immediately.

15 Closely monitor the patient during the MR procedure. If the patient reports sensations of heating or other unusual sensation, discontinue the MR procedure immediately and perform a thorough assessment of the situation.

16 RF surface coil decoupling failures can cause localized RF power deposition levels to reach excessive levels. The MR system operator will recognize such a failure as a set of concentric semicircles in the tissue on the associated MR image or as an unusual amount of image non-uniformity related to the position of the RF coil.

**The adoption of these guidelines will help to ensure that patient safety is maintained, especially as more conductive materials and electronically-activated devices are used in association with MR procedures.**

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# Guidelines for the Management of the Post-Operative Patient

IMRSER

There is controversy and confusion regarding the performance of a magnetic resonance (MR) procedure in a patient with a metallic implant or device during the post-operative period. Studies in the peer-reviewed literature have supported an MR procedure using an MR system operating at 1.5 Tesla or less, immediately after implantation, if a metallic object is a "passive implant" (i.e. there is no electronically- or magnetically-activated component associated with the operation of the device) and it is made from a non-ferromagnetic material, such as titanium, titanium alloy or nitinol. In fact, there are several reports that describe placement of vascular stents and other implants using MR-guided procedures that include the use of high-field-strength (1.5 Tesla) MR systems. Someone with a non-ferromagnetic, passive implant is allowed to enter the MR environment of a 1.5 Tesla or less, immediately after its implantation. Currently, there is little data to provide guidelines for MR environments using scanners operating at 3 Tesla or higher.

For an implant or device that exhibits "weakly magnetic" properties, such as certain stents, atrial septal defect occluders, ventricular septal defect occluders, patent ductus and arteriosus occluders, it is typically necessary to wait for six to eight weeks after implantation before performing an MR procedure or allowing the person to enter the MR environment of a scanner operating at 1.5 Tesla or less. This is because certain intravascular and intracavitary coils, stents, filters, and cardiac occluders, designated as being "weakly" ferromagnetic, become firmly incorporated into tissue six to eight weeks following placement. Retentive or counterforces provided by tissue ingrowth, scarring, or granulation essentially serve to prevent these objects from presenting risks or hazards to such individuals in the MR environment. Implants or devices that may be "weakly magnetic" but are rigidly fixed in the body, such as a bone screw, may be studied immediately after implantation. Specific information pertaining to the recommended post-operative waiting period may be found in the labeling or product insert for a "weakly magnetic" implant or device.

**Special Note:** If there is any concern regarding the integrity of the tissue with respect to its ability to retain the implant or object in place or the implant cannot be properly identified, the individual should not be exposed to the MR environment.

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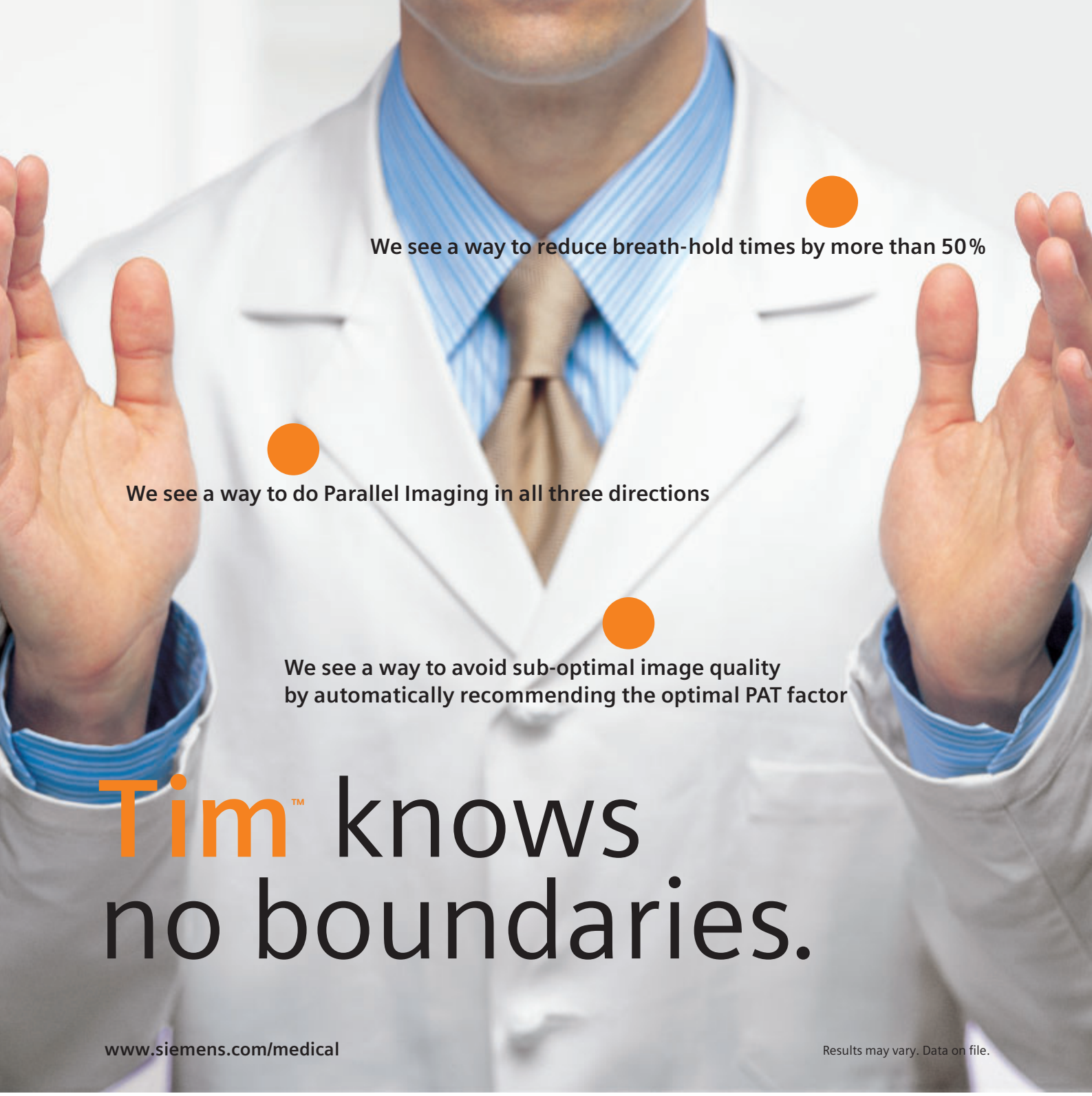


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# Annual CT/MR Users' Seminar Review

Barbara Cammisa
National Manager,
US MR Applications

In June 2003, the CT and MR Applications groups from the US had the pleasure of sponsoring our annual dual-modality users seminar for our global MAGNETOM and SOMATOM customers.

The MR group had a grand turnout of 125 MR customers from the US as well as our friends from Canada, Germany and other international patrons. It was a wonderful forum for our MAGNETOM users to share their experiences with their MAGNETOM friends.

The two-and-a-half day seminar took place in the entertaining and fun-filled city of New Orleans. Nancy Gillen, Vice President – US MR Division, kicked off with an invigorating presentation providing insight into what the future holds for MR. This fueled the excitement of our attendees who chose a profession in Magnetic Resonance Imaging.

It was our pleasure to have several of our Siemens customers speak at our seminar. Margaret King, from Raleigh MRI in North Carolina, consistently delivers invaluable tips for the technologists, which can be implemented immediately upon their return to their workplace. We asked Margaret to extend her usual one-hour lecture to two hours this year since she never seems to have enough time to answer all the questions or address the topics raised by the audience. As in the previous two years, Margaret's lecture was again the highest rated lecture of the seminar from the attendees.

Among our faculty was Tamara Lee from the Children's Hospital of Philadelphia. Tamara presented a Pediatric Cardiac Imaging lecture, which gave our users insight into the challenging task of imaging pediatric patients. Dr. Vamsi Narra from the Mallinkrodt Institute of Radiology expanded our knowledge of contrast enhanced MRA studies as well as VIBE imaging. Dr. Meng Law from New York University contributed to the subject of Spectroscopy along with Sheila Bero, one of our Advanced MR Applications Specialists.

Of course, our users seminar would not be complete without contributions from our talented and dedicated internal faculty of MR Applications Specialists, the MR R & D group, the Uptime Service Center and the MR Division. The topics of discussion from our internal staff ranged from Cardiac MRI to ACR Accreditation to "Pet Imaging". We also offered one-on-one Leonardo demonstrations (our multi modality workstation) to our attendees who were interested in learning about the Leonardo's post-processing capabilities.

The MR and CT Divisions from the US sponsored the surprise Friday night event that consisted of a genuine Marti Gras parade including floats, beads and music. At the end of the parade a private riverboat ride on the Creole Queen was waiting to meet all the participants for a night of food, fun and entertainment. It will be difficult to top this next year but we already have some great ideas in the pipeline!

Our annual user seminar demonstrates Siemens ongoing commitment to educating our MAGNETOM users in a variety of different platforms. We are in the midst of planning our seminar for next year. Once finalized, the information will be posted on the MAGNETOM World website at SiemensMedical.com/MAGNETOM-World as well as in the MAGNETOM Flash. We hope you will join us for another exciting seminar next year!


Proven


CREOLE
QUEEN

# Siemens Promotes a First-Ever Meeting Between MR and CT Users within Mercosur

By: Alessandra Wasilenko for
Siemens Medical Solutions Brazil

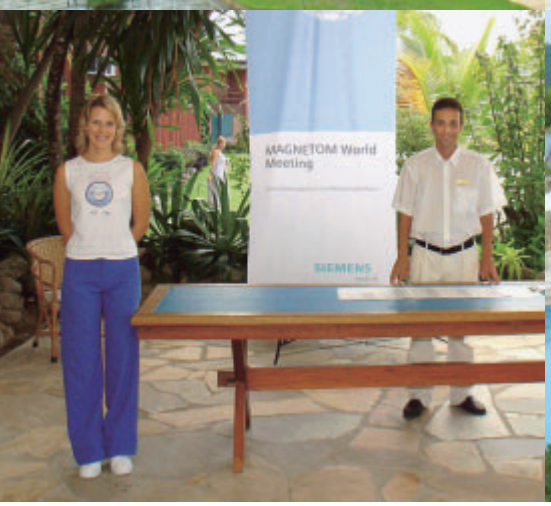

From June 6-8 in Angra dos Reis (RJ), Brazil, Siemens Medical held a first-ever meeting within Mercosur between radiology experts in the areas of Magnetic Resonance (MR) and Computerized Tomography (CT). Renowned users of Siemens equipment from Brazil and elsewhere had the opportunity to meet together and learn from each other. "The objective was to exchange experiences and update these professionals on diagnostic solutions and the latest trends in CT and MR in terms of advanced techniques and applications for post-processing procedures and studies", said Gustavo Ribeiro, Siemens Medical's Magnetic Resonance Modality Manager-Mercosur.

Twenty-three lecturers presented questions in the following areas: Neurology Program; News and New Technologies; Screening and Orthopedics Program; Thorax, Abdomen and Pelvis Program; Angiography and Cardiology Program, and Case Reports. One such lecturer was Dr. Filippo Cadermartini, from the Radiology and Research Department of the Erasmus Medical Center, Amsterdam,

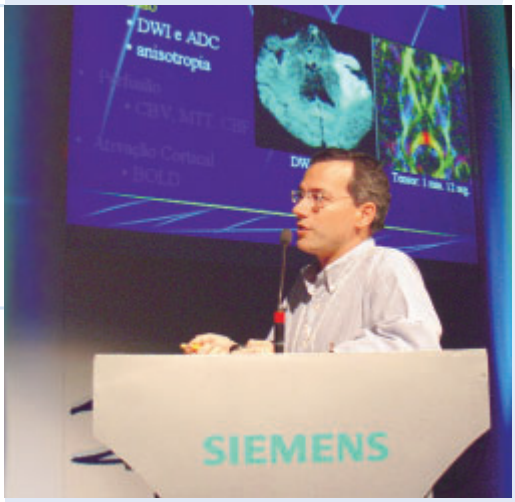

who spoke about screening techniques using a 32 row/second Multislice computerized tomography to perform virtual colonoscopy; and also about non-invasive angiography for treating coronary artery diseases and neurovascular applications. Lecturers from the Mercosur region discussed such themes as neurological applications in open systems, latest news in high field MR, multislice computed tomography, as well as the merger potential and protocols for PET, CT and MR images.

Roughly 70 % of Siemens' users offer their patients both diagnostic modes, which fact explains the union of CT and MR at the event. The presentations were directed towards the analysis of illnesses in which there exist experiences using both techniques. The idea of the meeting grew from Siemens Medical's awareness that there lacked uniformity of

# Brasil




information among users regarding similar equipment. The proposal received support from Siemens' international programs: MAGNETOM World, in the Magnetic Resonance area; and SOMATOM Life in the Computed Tomography area. These programs aim to disseminate information and develop loyalty among users. The number of participants was limited to the first 120 applicants. "This event marked the beginning of a series that will promote further interaction between the company and users. After all, it is by understanding and anticipating user needs that new solutions are developed. By uniting more than 100 users of similar equipment, the considerable interaction during and especially after the event was only to be expected – the networking of these professionals was multiplied", explains Paulo Gropp, Siemens Medical's Computed Tomography Business Manager – Latin America. On Sunday, June 8, the event program offered a free day allowing participants to enjoy one of the most fascinating ecological sites in Brazil.




**Dr. Romeu Cortes Domingues, director of the CDPI and Multi-Imagem (RJ) clinics. Neurology Program. Lecture: "Functional MR in brain tumors (Diffusion, Perfusion, Spectroscopy, Tractography and BOLD)".**

*"I thought this was an extremely important initiative on the part of Siemens, for we had the opportunity to exchange experiences with other colleagues and also learn a lot, not only as a lecturer. We see the work other people are doing in other cities; and each one has a different experience in a given area, pushing the discussion towards a more specific subject. So we exchange a lot of experiences not only in the scientific area, but also in the administrative field, which is very important. In addition to this scientific and administrative aspect, it is also very good to get together with colleagues on a social level. Siemens Brasil is experiencing a very positive period, both commercially as well as in services. As a result, what we see is considerable satisfaction from the radiology area towards the technology and services of Siemens. It is interesting and positive to see a company sponsoring an event such as this – which requires such investment of time and money – in a time of crisis. In hard times, nobody wants to invest; everybody is forced to cut costs. However, Siemens proves that it is prospering and believes that the country's economy is going to improve and people will begin buying again. This is why it is getting a head start. I think this is a vision of the future (...). Paulo Gropp and Gustavo Ribeiro deserve to be congratulated, as does the company. (...) And it is nice to see that the people using Siemens equipment here in Brazil are doing a great job. In watching the heart classes, as well as the tomography, neurology and that of other groups, we see that the company has sold to opinion-forming centers and that is good, for both the company and local specialists."*

*"I focused on citing cases from the Symphony Maestro Class because Siemens developed an equipment easy to work with. I can perform a complete neurological examination. The equipment is fantastic and can execute very thorough examinations: diffusion, perfusion, spectroscopy and tractography. Tractography is a diffusion-based image that Americans call tensor image. And we can do all this much faster and easier than in days gone by. (...) The equipment today is much quicker and easier to work with. Consequently, I can offer a complete exam and provide a better diagnosis to neurosurgeons and neurologists. I possess more tools so that my diagnosis as between a tumor or an inflammatory process is always accurate. So I tried to show in practice, with an example, how it has become easier to provide a diagnosis, giving us a lot more assurance. I want to show how these new techniques represent a major advancement. I believe there was even interaction between Siemens and certain key centers in the United States, such as Harvard University. We know that various software applications of theirs, such as for perfusion and tractography, resulted from our joint efforts. With these new techniques, Siemens has taken a significant leap forward (...)."*


**Dr. Martín Eleta, from the Hospital Italiano in Argentina and Radiology professor at the Federal University of Buenos Aires (AR). News and New Technologies Program. Lecture: "Experiences with PET, combining CT and MR".**

*"The event was very useful and interesting. We witnessed many new technologies that are being introduced at the centers. We were given the opportunity to see the clinical features of these new techniques. (...). This will be useful given the interaction we will have with potential contacts to take mutual advantage of what each one currently develops".*

*"My objective was to demonstrate the progress in Positron Emission Tomography using fusion images of PET, MR and CT and the utility of this method especially in oncology, cardiology and neurology. The diagnostic feature of the new method exhibits the complete anatomy and morphology together with metabolism, thereby making available a lot of information. (...)"*


**Dr. Paulo Schwartzman, Cardiology professor at the Federal University of Rio Grande do Sul, former-fellow of the Cardiovascular Imaging Service at Cleveland Clinic, Head Physician responsible for Cardiac Resonance at Hospital Mãe de Deus Center (RS) and Clínica X-Leme (PR). Angiography and Cardiology Program. Lecture: "Clinical applications of Cardiac Magnetic Resonance".**

*"The event was marvellous and very well organized. The lectures were good. The contacts were excellent. The lectures were top notch with outstanding image quality. I also think that the topics were well-divided: the mix was ideal. All imaging areas were discussed. I thought they were very good. (...) I work in the cardiovascular imaging area: I want to discuss my area of interest and I want others to see what I do. I want others to be able to carry out these exams. Likewise, there are people from the abdomen area and some doctors from the neurological area. In summary, this mixture is interesting and informative for all groups.*

*"My objective was to show that it is possible to conduct cardiac magnetic resonance using Siemens equipment. The examination is quick. I want to take the mystery out of the exam for people who think cardiac MR exams are too lengthy. Cardiac MR resonance as a whole can be a long exam, but I wanted to show the reality, that with Siemens equipment, especially, it is possible to run a thoroughly complete exam in just 30-35 minutes. I can therefore debunk the myth that cardiac MR takes up too much machine time and show where this examination stands in today's cardiology area and what its applications are."*

Brasil


**Dr. Pedro Guedes, Radiologist of Hospital Real Português and Serviço Real Imagem (PE). Thorax, Abdomen and Pelvis Program. Lecture: "MR and Endorectal Spectroscopy of the Prostrate Gland, how I do it".**

*"The event was outstanding not only in terms of people it reached, but also for the quality level of the lecturers, the large number of participants and the professionalism with which Siemens organized the event. Gustavo Ribeiro and Paulo Gropp deserve the special congratulations and I truly hope this event is repeated every year. The important thing in an event like this is not only to praise the good things being done, but also to deal with the problems we have with our equipment. That is, exchange experiences about our problems. To try and correct a problem with a solution that another colleague may perhaps have found. (...). After all, everyone here is a loyal Siemens customer. We all have similar Siemens equipment. Therefore, this interaction is what really counts."*

**Dr. Renato Mendonça, responsible for Medimagem's neuroradiology area at Beneficência Portuguesa Hospital; former President of the São Paulo Radiology Society; current President of the São Paulo Radiology Society's Scientific Commission (SP).**

*"(...) I was very impressed by the space in which the event took place. It was very well organized, well decorated. Lots of screens. I think the company outdid itself. I hereby congratulate all those responsible for having offered so many classes in such a breathtaking place. It is impossible to keep everyone in the rooms the entire time. I believe they obtained record audiences, because the majority of people that came attended the classes, in spite of the potential distraction of such beautiful surroundings. The level of presentations was very good. First world quality. (...). We can see that the quality of work Brazilian physicians are doing is on a par with our foreign colleagues. (...) I think Siemens deserves to be congratulated. The event was perfect, impeccable. (...) Believe me, I have participated in events held by other companies, but nothing comes even close to this one. It included examples from all over Brazil. I know a lot of people here; there are individuals from the northeast, the north, the southeast. There are people from the midwest. Siemens gathered a very representative sample of experts from all over Brazil. The event was represented in the way the company is represented throughout Brazil. This, to me, comes as a surprise; witness so many well-established bases. Everything – and everyone – was catered for. The company even took the caution of hiring an emergency rescue service in the event any 'oldies' had a stroke during the event. I appreciated this special attention given to us 'oldies'. We thank you."*

**Dr. Carlos Jader Feldman, Radiologist of the Diagnostic Investigation Service at Hospital Ernesto Dornelles and Instituto de Cardiologia, in Porto Alegre (RS).**

*"It was an excellent opportunity to participate in this new idea in Brazil. The event format was compact, we had interesting themes and the discussions were in-depth."*

**Arnaldo Lobo, Radiologist at Clínica Lobo, in Belém do Pará (PA).**

*"I was very enthusiastic about this initiative from Siemens. Firstly, because it was my first experience of this kind of event. Secondly, because of how I experienced the event, not only in terms of the presentation of technological progress, but also the quality of people invited to participate in the course. I believe that the exchange of information was very good and the future very promising. There should be at least one of these events every alternate year."*

Brasil

MAGNETOM World



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"With such a successful event, Siemens Medical Mercosur proved beyond all doubt the pride and confidence which we all share in the strengths of our South American continent. We were delighted with the outcome of the meeting: our main objective to promote and exchange knowledge between our customers exceeded our expectations. Much of the success was due to the invaluable contributions by some eminent radiologists who promoted some very stimulating discussions. One thing is for sure: we now have more ideas and opportunities to enable us to stay ahead of the field in the healthcare sector, which is exactly where we belong."

*Carlos Vallejos*
*Marketing Manager*














Brasil

# MAGNETOM World Meeting Cardiac Imaging Symposium for Asia

Tony Enright, Ph.D.
Clinical Marketing and Collaboration Manager
MR Asia Pacific

## Singapore, July 5, 2003

Cardiac MR (CMR) is of growing importance to diagnostic and interventional healthcare workers for cardiology services within the Asia region. Siemens recognises the needs and interests of this community in continuing education on the utilisation of CMR. This was the aim of MAGNETOM World's Cardiac symposium located in the beautiful city of Singapore. Participants from throughout the Asia region joined the symposium to hear clinicians from within their region who are involved in the state-of-the-art application of CMR techniques.

The meeting was jointly organised with the Singapore Chapter of Radiologists, Academy of Medicine, and the Singapore Radiological Society and Singapore Cardiac Society. "With the involvement of these societies this educational symposium was able to reach out to a wider community of cardiology, radiology, allied healthcare workers and the research community." Dr. Kevin Chen of Singapore General Hospital and Tan Ru San from the National Heart Center were joint chairpersons for the symposium.

A special focus of this symposium was to examine CMR from the perspective of cardiology experience from within the Asia region. Siemens collaborates with institutes in the Asia region where cardiology does play a strong role in CMR examinations, such as our speakers from Wakefield Hospital in Australia and Sir Run Run Shaw Heart Centre in Hong Kong (SRRSHC). Both institutes chose their MRI system for their cardiology needs, Siemens Maestro Class MAGNETOM Sonata.

Participants heard from Dr. Stephen Worthley, an interventional cardiologist located at Wakefield Hospital, and Dr. Ching Hon Luk, a consultant cardiologist from SRRSHC. Dr. Brett Cowan from the University of Auckland and Greenlane Hospital in New Zealand is involved at the forefront of rapid and advanced reporting techniques for cardiology. Dr. Renate Jerecic from Siemens Medical Solutions in Germany introduced the latest groundbreaking technologies in use by frontline researchers and clinicians alike, such as self-gated cardiac imaging*. "The ECG gating information is determined directly from the Siemens images, there are no wires attached to the patient for gating. This is outstanding technology reducing patient setup and removing the dependence on the ECG when patients have poor ECG signal. It also offers a solution for ultra-high field cardiac imaging where at clinical 3 T the magneto hydrodynamic effect can be more disruptive to the ECG measured by MRI scanners."

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

Dr. Brett Cowan

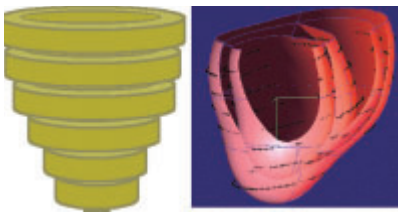
Cardiac MR Research Group
University of Auckland,
New Zealand

The Cardiac MRI Research Group lead by Dr. Brett Cowan and Dr. Alistair Young work in the area of rapid clinical analysis of MRI images and are well established as a core lab for large international pharmaceutical trials. They have a depth of expertise in both clinical imaging and high-tech mathematical modeling of the heart. Their work was recognized in July of this year with the awarding of the 2003 Computerworld Excellence in IT in Biotechnology prize.

## Ejection fraction in 5 mins – rapid reporting of function – latest techniques

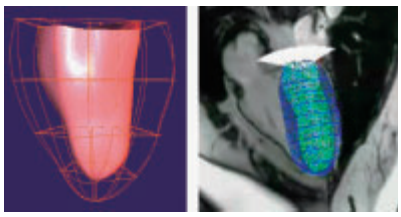
The focus of Dr. Cowan's lecture was on the reporting needs of cardiology and radiology, when working with MR images of the heart – "a rapid software analysis which quantifies global function and other diagnostic quantities with a high degree of accuracy".

"MRI now delivers superb quality cardiac imaging that is rapid, with real-time imaging a reality. However, the needs of cardiology extend beyond the high resolution anatomical images from MR. For patient management and prognosis cardiology requires quantities such as end diastolic volume (EDV), end systolic volume (ESV), and myocardial mass. MR can also provide information on regional wall motion, wall thickening and mass. But MR needs rapid and accurate image analysis for reporting."



*a* *b*

**Figure 1** *a) 2D conventional heart model constructed from separate slices, and b) 3D heart model.*



*a* *b*

**Figure 2** *a) 3D cardiac model of left ventricle, wire mesh for epicardium and surface for endocaridum, b) model fit to dynamic (cine) images.*

Dr. Cowan described the issues associated with the image analysis based on the conventional 2D approaches such as those shown in figure 1a:

- Contouring the endocardium and epicardium is time consuming
- All images from a short axis stack must be contoured
- The ventricle is not composed of a series of disks
- Wall thickening can only be measured in the available slices
- Volume in the most basal slice is difficult to calculate

Additionally, failure to account for the through plane motion of the base of the heart can lead to a significant error in volumetric changes.

These issues are addressed by a "fully beating" 3D model of the heart (Fig. 1b). Siemens is collaborating with the Auckland group to realise the power of a 3D analysis of cardiac function in the ARGUS product. Developed by the Auckland group, the 3D model* has a finite element computer representation of the heart dividing the ventricle into a patch-work of small surfaces which can deform to match a patient's heart shape throughout the cardiac cycle. Figure 2a shows the model for the left ventricle, here demonstrating the epicardium shown as a wire mesh and the endocardium shown as a surface display. "This sets a new standard in the way the global function of the left ventricle is measured."

In addition to the advantages in reporting the heart's global function, now that the position of the endocardium and epicardium through the cardiac cycle is known, it is also possible and even convenient to perform any kind of regional analysis on the heart. Since these regions can be mathematically traced though the cardiac cycle, an EDV, ESV, stroke volume, mass and ejection fraction can be calculated for each separate region.

In the example of figure 3, a patient who has had an infarct, the ejection fraction in the infero-lateral region is 24.7 % and the time-volume curve is shown in green. In contrast, the anterior and antero-lateral regions which were unaffected by the infarct have local ejection fractions of 71.6 and 73.1 % respectively as are shown on the bottom two time-volume curves.

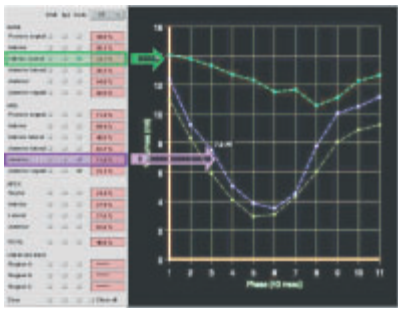


**Figure 3** *Regional Analysis and Reporting – volumetric changes from infero-lateral region shown in green annotation, and antero-lateral shown in purple.*

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

Dr. Stephen Worthley

Director of Cardiovascular Imaging
Wakefield Hospital, Adelaide,
Australia

Dr. Worthley's initial address entitled "Non-invasive Myocardial Imaging with MRI" was the first in a series of lectures for the symposium – "MR in Cardiovascular Diagnosis".

## Non-invasive myocardial imaging with MRI

Participants were presented a "potpourri" of clinical examples from Wakefield Hospital which served to demonstrate and introduce cardiovascular magnetic resonance imaging (CMR) for anatomy and morphology, cardiac masses, structural abnormalities, viability, ischemia and valve abnormalities.

Dr. Worthley highlighted the diagnostic strengths that CMR offers cardiologists, and in context with existing and conventional imaging techniques that are routinely applied today to a range of cardiac diseases – for instance

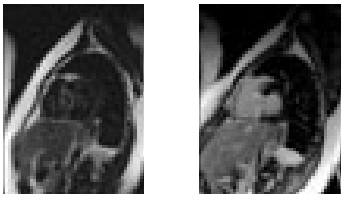
"In pericardial disease MR is probably the modality of choice for pericardial constriction where echocardiography doesn't always provide the amount of structural and functional information often required for diagnosis."

In imaging of myocardial perfusion* the resolution offered by CMR is superior to that offered by SPECT based techniques – the resolution from CMR allows one to evaluate transmural effects of ischemia.

Most exciting from CMR is myocardial viability. Assessed with the late enhancement technique, presently there is no comparison in terms of spatial resolution. The superior resolution afforded by MR allows accurate evaluation of the transmural extent of myocardial scarring, and results are obtained within 15-20 minutes of contrast administration.

Viability imaging from CMR has a contribution to make to Dr. Worthley's recent interventional work using Percutaneous Transluminal Septal Myocardial Ablation (PTSMA). Patients with thickening of the septum / myocardium ("hypertrophic cardiomyopathy") may have problems with obstruction to the ejection of blood into the aorta due to this thickened region of muscle. Here alcohol serves to occlude the selected arterial branch, causing a localised infarction, reducing this obstruction. MRI is used to assess the extent of localised infarction and the resulting changes to left ventricular function. Perfusion MRI enables an assessment of the extent of perfusion disruption to the myocardium, and the late enhancement technique for viability demonstrates the extent of the localised infarction. A practical note to the late enhancement technique for this procedure is that the infarction may not be shown hyperintense immediately following the PTSMA procedure as the occluded artery prevents the contrast agent gadolinium from entering the area. However, a rim enhancement of the infarct region can be observed thereby delineating the boundaries (see example in figure 1a. Dr. Worthley demonstrated cases highlighting the successful combination of PTSMA and CMR for therapeutic intervention in patients with hypertrophic cardiomyopathy.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*



*a* *b*

**Figure 1** *Late enhancement viability imaging* for assessment of hypertropic cardiomyopathy patient treated with Percutaneous Transluminal Septal Myocardial Ablation (PTSMA) – a) initial viability imaging showing rim enhancement delineating boundaries of infarct region, and b) final viability images confirming infarct.*

## Non-invasive coronary and plaque imaging

This second lecture was directed at some of the most challenging areas of CMR – coronary artery magnetic resonance angiography (CMRA) and the characterisation of atherosclerotic plaque.

A review of the techniques used in CMRA are:

- Breath-hold versus navigator techniques
- Contrast versus non-contrast

"In many cases the breath-hold examination is sufficient for evaluation of the coronaries and the longer examination using navigator is not required. This is certainly an advantage in time saving and rapid review of the positioning results – capturing the coronary segments of interest. In difficult cases where breath-hold is not possible the navigator technique offers another solution."

For CMRA Dr. Worthley highlighted that current clinical studies have largely concluded MR is sensitive to stenosis but its major limitation remains the specificity of the technique for routine use. Dr. Worthley's institution also utiliseses 16-slice

multi-detector CT (MDCT). The participants were able to see a comparison between high resolution CMRA and the MDCT for coronary artery imaging, such as shown in figure 2.

A particular focus of research for Dr. Worthley has been imaging of atherosclerotic plaque for which he completed his PhD at Mt Sinai in New York. "Often the severity of stenosis is a poor predictor for risk of myocardial infarction. This has led to the necessity for lesion characterisation to identify plaque vulnerability. MRI can characterise the plaque components – fibrous cap, lipid pool, calcifications ... and it is these components of the atherosclerotic plaque that are better predictors for myocardial infarction."

While the routine use of MRI for high resolution imaging of coronary arteries still poses challenges, plaque composition in carotid arteries is already feasible. Dr. Worthley utilises a specialised RF coil on Siemens MAGNETOM Sonata for bilateral coverage of both carotid arteries yielding high resolution images for plaque characterisation.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

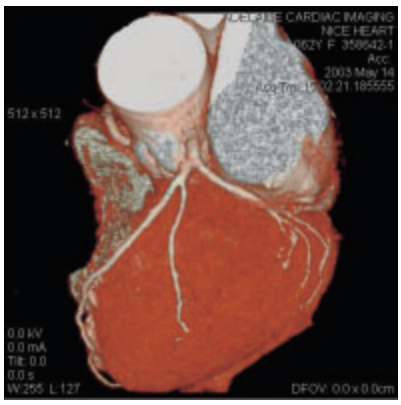



**Figure 2** *Imaging of Coronary Arteries with multi-detector CT at Wakefield Hospital (Siemens SOMATOM Sensation-16).*

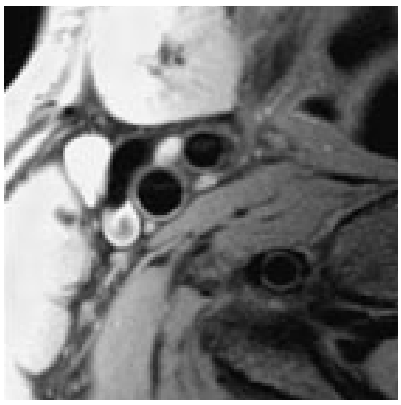


**Figure 3** *Imaging of Corotid Arteries with bilateral carotid coil at Wakefield Hospital. Acquisition taken immediately above the bifurcation showing lumen (Siemens MAGNETOM Sonata).*

**Dr. Ching Hon Luk**

**Sir Run Run Shaw Heart Centre St Teresa's Hospial, Hong Kong**

Sir Run Run Shaw Heart and Diagnostic Centre (SRRSHC) is one of the earliest heart centers located in the Kowloon peninsula, founded by Sir Run Run Shaw through a generous donation. It is operated and run through St Teresa's Hospital, located in Kowloon Peninsula, Hong Kong. Sir Run Run Shaw Heart and Diagnostic Center is unique in that cardiology plays an important role in cardiac MR imaging. The MR is situated within the Heart Center and is an integral part of the center. A significant number of cases with positive findings on MR are catheterized and the results made known to the MR team. Patients who underwent angioplasty are actively followed up using cardiac MR. The close co-operation of radiologists and cardiologists provide the necessary feedback for quality interpretation of the MR imaging.

## Detection of myocardial ischemia with perfusion imaging and dobutamine stress MR*

Dr. Luk, a consultant cardiologist with SRRSHC, began his lecture by describing the operation of this unique centre, its team of professionals, and why they chose MRI for

their patients. "At SRRSHC we are particularly interested in the detection and diagnosis of disease early within the ischemic cascade – diagnosis of subendocardial perfusion deficit and transmural perfusion deficit. Our clinical questions are:

- What is wrong with patients having chest pain?
- Does a patient require revascularization procedure?
- Treatment follow-up?
- Cardiac functional assessment for non-cardiac surgery?"

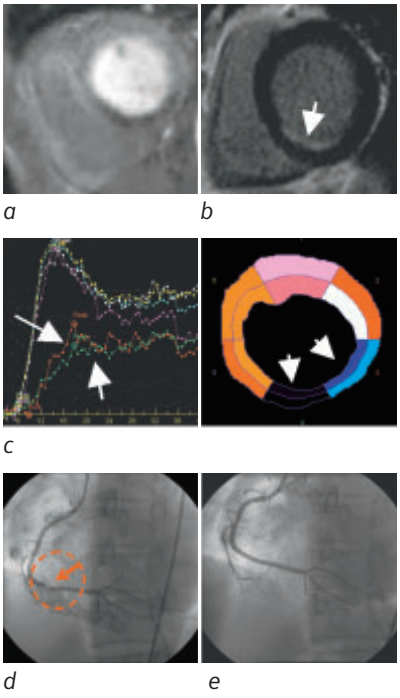
The centre has existing catheterization labs for angiogram and angioplasty procedures. "What was needed in our centre was a non-invasive diagnostic tool for examining ischemic heart diseases.

Our belief: cardiac MR provides ample diagnostic information non-invasively."

Dr. Luk described the equipment requirements for CMR. Sir Run Run Shaw Heart Centre chose Siemens Maestro Class MAGNETOM Sonata, a highly advanced MR imaging scanner, for non-invasive examination of ischemic heart diseases.

Dr. Luk emphasised the current knowledge gap that generally applies for cardiologists new to working directly with the MRI technologies, which are at an advanced level in cardiovascular MR imaging (CMR), and therefore the need for strong vendor support to overcome this initial barrier. "Siemens provides this support for our team and in our case included an onsite clinical scientist from Siemens cardiac research and development group at Northwestern University in Chicago."

Dr. Luk's lecture material provided participants with a comprehensive overview of perfusion imaging:



*a* *b* *c* *d* *e*

**Figure 1** *54 year old male patient with symptoms of chest discomfort unrelated to exertion. Patient is a non-smoker with no history of diabetes or hypertension. a) Stress perfusion image showing extent of perfusion deficit associated with RCA prior to stenting procedure, b) late enhancement image demonstrating subendocardial infarct, c) semi-quantitative perfusion curves displaying sector anlysis of contrast transport through the myocardium. The arrows demonstrate the areas of risk highlighted by the perfusion software Dynamic Signal Analysis, d) X-ray angiogram before stenting, and e) angiogram after stenting.*

**1)** beginning with an overview of existing imaging techniques used in cardiology for routine diagnosis of ischemic disease and the sensitivity of these in comparison with MRI,

**2)** physiological changes to myocardial perfusion under the influence of vasodilator stress agents,

**3)** how perfusion MR imaging using contrast works,

**4)** the physics of imaging sequences used for perfusion imaging, and

**5)** the key issues in image quality and their interrelationships – temporal resolution, spatial resolution, image signal-to-noise and anatomical coverage.

Cardiac perfusion imaging operates at the advanced level of MRI technologies. SRRSHC is fully equipped with state-of-the-art MRI equipment including specialised radiofrequency (RF) coils for high performance parallel imaging. Patients are examined using a 12-channel coil system (Siemens dual 6-pack RF coil pair). Parallel imaging and TrueFISP technologies are taken full advantage of in imaging of ischemic heart disease.

A typical imaging protocol at SRRSHC for ischemic patients is described:

**1.** 4-chamber cine,

**2.** Localizers: basal, mid-ventricular and apical slices,

**3.** Adenosine injection for 4-6 min

→ cardiologist attending the session,

**4.** Contrast injection + perfusion imaging (stress),

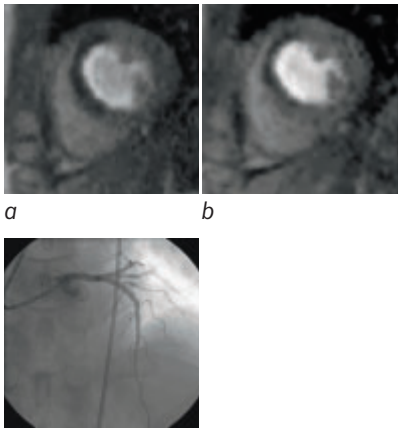
**5.** Wait for 10 min

→ perform cine imaging for cardiac function during this wait period,

**6.** Contrast injection + perfusion imaging (at rest).

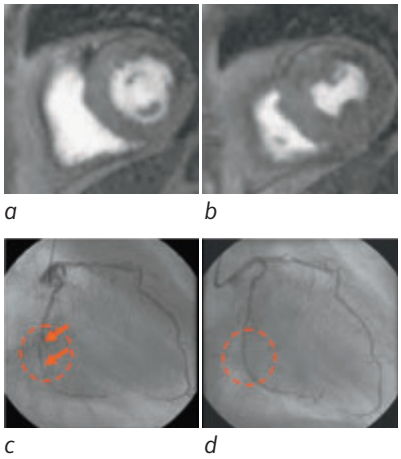
Dr. Luk commented on the advantages of having available both imaging and semi-quantitative reporting for diagnosis. "In the perfusion analysis the reported upslope of the curve is typically most sensitive to perfusion deficit." Patient contrast dosage at SRRSHC has been optimised for semi-quantitative analysis.

Dr. Luk had many clinical case examples to share with participants. Figure 1 shows diagnostic images from the typical caseload at SRRSHC – this patient a 54 year old male presenting with chest discomfort unrelated to exertion, is a non-smoker and with no history of diabetes



a b c

**Figure 2** *Imaging of a 52 year old male patient following acute myocardial infarct. a) rest perfusion* image, b) stress perfusion image*, and c) X-ray angiogram.*



a b c d

**Figure 3** *76 year old female with previous PTCS and stenting on LAD, now suffering symptoms of frequent chest pain. a) and b) stress perfusion images more basal and apical respectively, c) X-ray angiogram showing multiple stenoses in LCX, d) angiogram following stenting of LCX.*

or hypertension. The clinical question is whether this patient has CAD? Non-invasive MR imaging answered this question. MR perfusion imaging at rest showed only mild hypo-perfusion, but under stress (Fig. 1a) demonstrates a significant region of hypo-enhancement associated with perfusion deficit from the RCA. MR viability imaging, figure 1b, indicates a small subendocardial infarct. Semi-quantitative perfusion reported from software analysis (Fig. 1c – Siemens Dynamic Signal Analysis) identifies sectors at risk with delayed perfusion, in this case related to the RCA. Figure 1d demonstrates the angiographic confirmation of significant stenosis in the RCA, and figure 1e the angiographic results following intervention.

A second case presented by Dr. Luk involves a 52 year old patient who received MR perfusion imaging following acute myocardial infarct. Perfusion imaging demonstrates hypoperfusion of the infarcted area both at rest and at stress (Figs. 2a and 2b respectively). Figure 2c shows the follow-up angiogram. MR provided a beautiful demonstration of the microvascular changes after acute myocardial infract.

Figure 3 shows imaging of a 76 year old patient who received percutaneous transluminal coronary stenting (PTCS) on the LAD 6 years previously, now presenting with frequent symptoms of chest pain. The clinical questions are:

- follow-up from PTCS, and
- reasons for chest pain.

MR Perfusion imaging demonstrated hypoenhancement associated with perfusion deficit from the LCX (see Figs. 3a and 3b). X-ray angiographic examination, shown in figure 3c, confirmed multiple significant stenosis in the LCX artery.

In addition to perfusion imaging, Dr. Luk presented the dobutamine stress MR (DSMR) technique used at SRRSHC for imaging wall motion abnormality that is the result of significant stenosed coronary arteries. "Dobutamine stress MR may well prove to be significantly more sensitive and specific at detecting ischemia than the more routinely practiced dobutamine stress echocardiography."

**Figure 4** *Sir Run Run Shaw Heart Centre, St Teresa's Hospital, Hong Kong*

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

# MAGNETOM Forum 2003 – A Norwegian MAGNETOM World Users Meeting

Peter Kreisler, Ph.D.
Collaborations & Applications, Erlangen

The seventh Norwegian MAGNETOM users meeting took place between October 16 and 18 in the historic Terminus hotel in Bergen, on the western coast of Norway. We were pleased to be able to welcome more than 100 persons from 23 centres, including radiologists, technicians and physicists, to our meeting.

The meeting, as in previous years, was well organized by Siemens Norway in a close collaboration with Prof. Hans Jörgen Smith and Eldrid Winther-Larssen from Rikshospitalet Oslo.

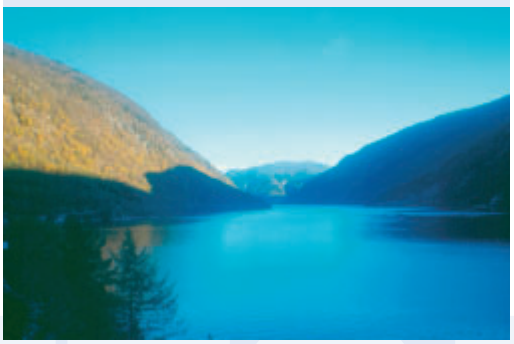
The clinical, technical and educational talks gave a valuable overview on the routine clinical and scientific activities in Norway. The entire human body was addressed: from perfusion and fMRI studies in the brain, to heart, pancreas and colon and to orthopaedics. A large proportion of the presentations were given by radiologists and physicists from the local Haukeland University in Bergen.

The radiographers' session Friday afternoon was an ideal forum for discussing practical issues of daily work.

In a special physics session, Dr. Klaus Scheffler from the University Hospital of Basel, Switzerland presented details on signal generation in Hyper-Echo sequences.

An important component in meetings like this is the informal and very fruitful discussions between colleagues from different centres during the breaks and in the evenings. Such communication will initiate new collaborations and intensify existing ones, helping to build up a strong national network embedded in the worldwide MAGNETOM World community.

Many thanks again to the organizers and supporters of this meeting for a very polished performance.



# MAGNETOM World Activities in India

Mr. Ajay Mittal
MR Marketing
Siemens Medical Solutions,
India

## MAGNETOM World Meeting Mumbai 23 to 25 May 2003

Siemens India hosted the MAGNETOM World meeting for eighty 1.0 and 1.5 T users in May 2003. The Renaissance Hotel, overlooking the serene Powai lake, provided a fantastic setting for the meeting. The three day event was inaugurated by Mr. J. Schubert, Managing Director Siemens Limited, India and the welcome address was delivered by Mr. Heinrich von Wulfen, Executive Vice President, Siemens India Medical Solutions. Everything was efficiently organised by Mr. Ajay Mittal, Chief Manager, MR Marketing Siemens India Medical Solutions. The highly interactive atmosphere was charged with MRI specialists sharing their practical experiences.

Following the inauguration ceremony and welcome address, Mr. Rudolf Hahn from Siemens AG, Germany gave a talk on MAGNETOM World concepts. The following day presented highly interactive sessions on MR Neurology, Spectroscopy, MR Cardiac, MR Orthopedic imaging, MR Angiography and MR Body imaging. International luminaries Dr. Meng Law – Assistant Professor of Radiology, NYU School of Medicine and Dr. Schneider of the University of Homburg shared their valuable knowledge. Dr. Stefan Roell from Siemens Spectroscopy development group highlighted the use of spectroscopy in clinical routine. Dr. Schneider enlightened us on subjects covering technique and sequences in Cardiac MR , Viability* Study and Cardiac Perfusion.

A number of speakers from India shared their knowledge and experience in various applications including Angiography, Spine and Joints imaging, Cardiac and Abdomen imaging. Dr. Milind Dhamankar highlighted newer developments in MR with a focus on helping radiologists understand their needs and make informed decisions. This approach to upgrades and investments was very well received. The fruitful discussions have helped radiologists to implement optimum utilization of existing applications and focus on future planning, investments and decisions.

The ultimate goal of the meeting was to create a sense on belonging to the MAGNETOM World. We proudly reached this goal: the meeting proved to be highly beneficial for all the participants. Much praise was justly bestowed on Siemens India and there was unanimous eagerness to attend many more such interactive meetings in the future.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

# India
# MAGNETOM World
# Mumbai


## MR Spectroscopy Workshop, Mumbai 27 to 28 May, 2003

MR Spectroscopy immediately followed the MR imaging workshop. With workflow optimization through *syngo* MR, it is gaining wider acceptance in clinical routine. A dedicated workshop on MR Spectroscopy focused on educating users about the newer developments. Users interacted with specialists in this field including Dr. Meng Law from NYU School of Medicine, and Dr. Stefan Roell and Ms. Mariane Vorbuchner, both from Siemens Medical Solutions, Erlangen. The hands-on approach was appreciated by one and all.

MAGNETOM World



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Dr. Radhesh S.,
Consultant Radiologist,
Elbit Diagnostics, Bangalore

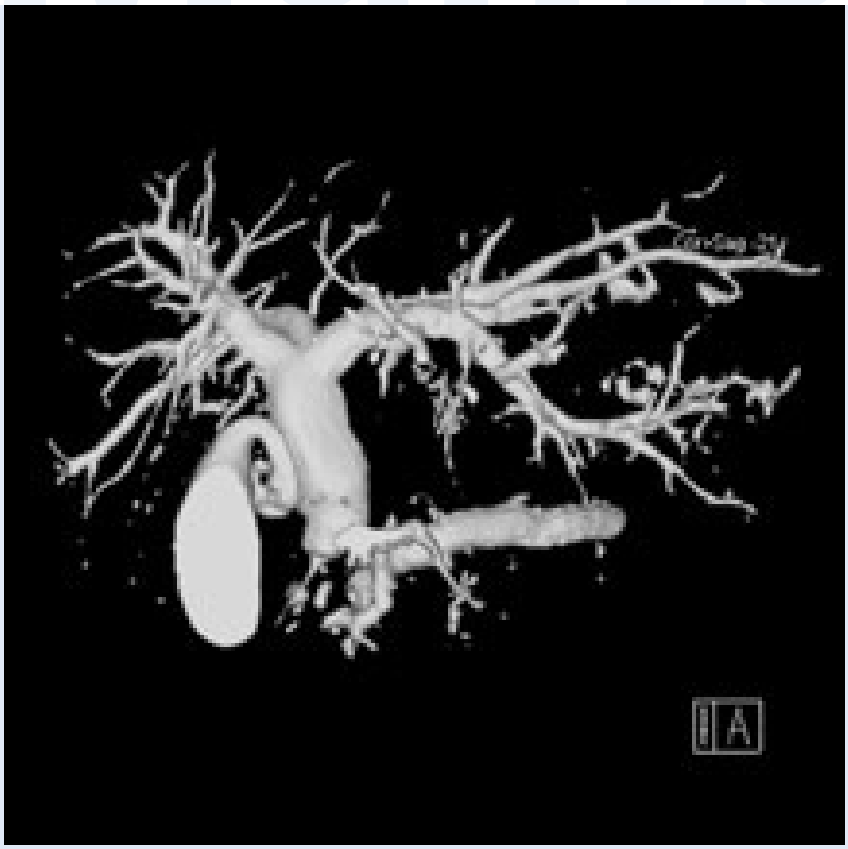
"I congratulate and offer my appreciation to Siemens India for the way it has brought together national and international speakers to share their thoughts on current MRI practices.

I would describe these programmes as "a common platform for sharing knowledge". The workshops on Proton Spectroscopy and Cardiovascular imaging were well organized: they had excellent material and were very interactive. In a nutshell, it all bore a stamp of class. I look forward to more of such workshops and wish Siemens India the very best for their future programmes."

Dr. Bharat Aggarwal,
DCA Imaging Centre
New Delhi

"To sum-up, everyone went back home with some positive experiences and new thoughts on how to better utilize their scanners, which applications to expand and where to invest next (and where not)."

Mumbai



*3D MRCP*
*Courtesy – DCA Imaging Centre, New Delhi, India.*

## Clinical test sites for Work-in Progress (WIP) sequences:

The application team in close cooperation with our customers has tested some WIP sequences like 3D myelography, 3D RESTORE sequence with 2D PACE for free breathing 3D MRCP. These WIP sequences were installed at DCA Imaging Centre Delhi, Mallaya Hospital Bangalore, AIIMS New Delhi. Excellent feedback has been received and as a result optimized protocols based on the feedback will be available in the upcoming software release, *syngo* MR 2004A.

## MR Cardiovascular Workshop, Hyderabad 22 to 23rd August, 2003.

MR Cardiac imaging is an emerging application in India. Siemens invited experienced users to a workshop to share their experiences with the participants.

Dr. Joerg Barkhausen from University of Essen and Dr. Carmel Hayes from Siemens AG shared their valuable clinical and practical know how with the Siemens Cardiac Imaging users. The workshop included lecture sessions and hands-on sessions and was warmly appreciated by all participants.

Siemens is the leader in Magnetic Resonance Imaging in India and has over 50 % market share in the 1.5 T systems in the country. Siemens has heavily invested in educational programmes. We are thankful to our esteemed customers for their excellent feedback and support.

India

MAGNETOM World

# Siemens MAGNETOM User Club (SMUC) Meeting in Ängelholm, Sweden...

Andreas Piringer
Product Manager MR
Medical Imaging & Therapy
Sweden/Finland/Iceland

## ...a meeting that had everything, including UFO's!

Congratulations and thanks to Andreas Piringer (MR Product Manager) and Anita Larsson (Marketing Assistant), who organized this two-day user meeting in collaboration with Elenor Thelander and Rolf Larsson, MR assistants, and Eva Bjärtun, Head of Radiology Section of Ängelholm Hospital, a small regional hospital in a town beautifully located on the west coast of Sweden. The meeting took place at the Klitterbyn conference centre in the town, and was opened by the local "lergöksorkestern", the only "clay cuckoo orchestra" in the world and a thoroughly original musical welcome to the 15 invited speakers, including the Siemens representatives.

The meeting was a valuable opportunity for customers to come together to exchange experiences, to learn about ongoing projects at different MR-locations and to get the latest product information from Siemens Medical Solutions.

## 25 September 2003

The Norwegian Application Specialist, Eldrid Whinter-Larssen (Oslo), gave a presentation on the new techniques iPAT and PACE and their advantages in abdominal imaging.

Dr. Katarina Håkansson from Kalmar made a speech on acute abdominal MR. She showed some very interesting cases made on their MAGNETOM Symphony (upgraded Vision).

Dr. Thomas Larsson from Södersjukhuset, Stockholm, presented their first clinical experience of cardiac imaging on a MAGNETOM Symphony Quantum. He showed functional Cardiac MR (CMR) cases and also images of late enhancement studies with excellent image quality.

One of the most exciting presentations was by Lars Erik Olsson, Amersham Health AB. Lars Erik talked about the development of hyperpolarized contrast agents for MR and offered a review of what hyper polarization is and what we could gain from it, as well as discussing the future of the technique.

Sara Brockstedt gave an enjoyable talk on diffusion tensor imaging, one of the ongoing projects at the MAGNETOM Allegra 3 T head scanner in Lund.

The Siemens Product Specialist on workstations – Lisa Lindfors – gave a presentation on the new Leonardo workstation software. She also showed some very effective VRT studies in real-time, which were highly appreciated by the audience.

Siemens service manager Volker Sundberg and Johan Olsrud from Lund discussed a very important topic – MR safety. Volker covered the system part (magnet hazards, etc.) and Johan concentrated on the clinical part (clips, SAR, etc.).

After lunch we offered three parallel sessions covering radiographers, doctors and physicists:

Siemens Application Specialist Agneta Rydman had her own corner – "Agneta's corner" – where tips and tricks at the Numaris and the *syngo* platform were discussed.

At the doctor session, 4 doctors from Ängelholm hospital discussed patient cases with their Swedish colleagues in a very open way.

Sara Brockstedt introduced the audience to the IDEA platform. She showed the workflow when a new sequence is developed, the different parts of IDEA and how these parts basically work.

Siemens Product Manager Andreas Piringer rounded off the day with a brief summary of the history of fast MR imaging and introduced the Parallel imaging technique, some application hints and some thoughts about the future of iPAT.

In the evening, we strolled in the woods of Ängelholm and were given a very interesting explanation of the famous UFO that is alleged to have landed on the coast of Ängelholm in the 60 s. Apparently, NASA has all the available information of this very special and top-secret x-file case. If there were any extra-terrestrials camping out in the woods of Ängelholm that evening, they kept well out of sight and did not delay our sumptuous dinner party at the Klitterhus hotel, along the coast. The band "Heartbreakers" gave a memorable show and for most us, how could we resist the urge to dance? Scandinavian cool had really turned up the heat.

## 26 September 2003

Siemens Product Manager Zoltan Vermes gave an excellent presentation of the news about CMR and also introduced new WIPs for the Siemens CMR package. The audience was very enthusiastic and it seems that this talk has triggered some of the clinics to do more, including implementing CMR on their own systems. At the next meeting we will see how many have actually managed to start CMR in their hospitals.

Finally, Volker Sundberg informed us all about news from the MR Service

# Sweden
# MUser Meeting
# Malmö

(CS sales, organization, remote service) and Andreas Piringer talked about communication in terms of new Sweden Application Scientist Magnus Karlsson, MAGNETOM World, SMUC, CS-Sales, MR training and syngo workshops.

The first user meeting in Sweden took place at the University Hospital in Malmö in 1994. This means that we will celebrate the tenth anniversary of this first meeting next year. Malmö has eagerly accepted the role of host for this celebratory meeting. We will also be able to show members and participators the new diagnostic centre (MAS-DC) in Malmö, equipped with 4 new fully loaded MR-scanners, as well as Siemens CT, angiography, digital X-ray, nuclear medicine and ultrasound. The meeting will be something special, we can assure you!

# MR Colonography as an Interdisciplinary Cooperative Project

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## Background

Colorectal carcinoma (CRC) is a frequently encountered disease with a high mortality in the Western world. According to statistics, after bronchial carcinoma, CRC is the second most common cancer-related cause of death in Germany. Studies performed by the Robert Koch Institute reveal that 51,700 people developed colorectal carcinoma in 1999 alone, and every year over 30,000 die as a result of this disease. Consequently, the lifetime risk of developing CRC in Germany is 4-6 %, and depends greatly on age. In particular after the age of 50, the incidence of the tumor rises exponentially [1].

In light of the high incidence and mortality associated with colorectal carcinoma, major efforts are being made in the area of primary and secondary prevention for economic considerations as well. Primary prevention encompasses the application of protective measures to prevent the formation of adenoma and carcinoma. Secondary prevention involves the detection of precursors to colorectal carcinoma, along with their treatment prior to malignant degeneration, and the detection of early carcinomas in primarily curable stages.

However, since only a small percentage of the population pays any attention to the primary prevention of colorectal carcinoma, preventive measures involving the early detection of polyps and carcinoma become all the more important. The data show that the incidence of intestinal cancer can be reduced by 20 percent by performing an occult blood test starting at the age of 55 [2].

Flexible sigmoidoscopy markedly reduces the mortality of colorectal carcinoma [3]. However, one serious disadvantage is the inability to inspect the proximal sections of the colon. Lieberman was able to show that 50-60 % of all patients with advanced proximal adenomas exhibit no distal polyps [4].

Due to the low sensitivity of the occult blood test and high number of unnoticed lesions during a sigmoidoscopy, colonoscopy is today regarded as the screening procedure of choice from a medical and financial point of view. The American National Polyp Study has clearly shown that up to 90 % of intestinal cancers can be prevented by rigorous polypectomy of cancer precursors [5]. It is in this context that health insurance plans in Germany have added colonoscopy to their early cancer detection program as of October 1, 2002.

One significant advantage to colonoscopy as a screening method is that detected polypous changes can be removed in a single procedure. The disadvantages include the necessary intestinal cleansing, discomfort during the examination, frequently required sedatives and analgesics, along with the risk of perforation.

Advances in computerized tomography and magnetic resonance imaging have now made it possible to noninvasively generate two- and three-dimensional images of the large intestine, enabling a virtual flight through the colon possibly comparable to conventional endoscopy. In the future, this might yield an early intestinal cancer visualization procedure in addition to the aforementioned methods [6].

However, at this point we only have a very limited amount of data comparing virtual colonography with colonoscopy, the current gold standard, in the diagnosis of colorectal lesions. Noninvasive colonographies are therefore not yet suitable for wide-scale use and early cancer detection.

As a result, further prospective studies are required to evaluate its significance in the diagnosis of colorectal lesions.

This is the stated objective of the Ludwigshafen MR colonography project, which will be introduced below.

## Current research

Initial studies with so-called CT colonography revealed a sensitivity level relative to conventional colonoscopy of 91 % for polyps larger than 10 mm [7, 8]. In addition to this limitation in comparison with endoscopy, the disadvantage to CT colonography is that it involves significant radiation exposure.

MR colonography makes it possible to image the colon without radiation exposure [9, 10]. A polyp detection sensitivity similar to that for CT colonography was achieved during initial studies [11, 12, 13]. Another advantage over computerized tomography lies in the use of safe i.v. contrast media, which lack the known nephrotoxicity, and exhibit a lower risk profile [14, 15].

Initial studies comparing MR colonography with conventional colonoscopy in the detection of colorectal lesions revealed a high degree of congruence between both methods for polyps larger than 10 mm [11, 12]. Luboldt et al. achieved a sensitivity of 96 % for lesions larger than 10 mm with MR colonography [11].

**"Fecal tagging"*** is a new method for contrasting the colon in MR colonography. Oral intestinal cleansing is here unnecessary. The patient takes a barium-containing nutritional supplement with each meal for 36 hours before the study. In all sequential MR procedures, this results in a homogenously black stool and good delineation from the intestinal wall. Initial results show a high sensitivity of 90 % for the detection of colorectal lesions [13]. According to the literature and our own experience, complete colonoscopy with intubation of the caecum is possible in 90-95 % of all examinations [16-18]. This is where virtual colonoscopy is at an advantage, since all sections of the intestine can generally be examined with MR colonography, thereby enabling the detection of pathological changes in colon segments that were not examined. In addition, MR colonography allows an evaluation of the entire large intestine in the presence of stenosing tumors in the distal colon that cannot be crossed by an endoscope. In a study of 29 patients with endoscopically uncrossable colorectal carcinoma, virtual colonoscopies revealed 2 additional carcinomas along with 24 more polyps proximal to the stenosis [19].

Based on these data, colonoscopy remains the method of choice, in particular for detecting the smallest adenomas. Additional comparative studies and improved detection for even the smallest polyps are required for the wide-scale use of MR colonography in the detection of colorectal lesions.

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

## Ludwigshafen MR colonography project

### Interdisciplinary cooperation

Medical Clinic C (focus on gastroenterology) and the Central Institute for Diagnostic and Interventional Radiology have been cooperating closely with each other at the Ludwigshafen teaching hospital for several years. In 2001, an interdisciplinary working group was established to focus intensively on magnetic resonance imaging in the diagnosis of gastroenterological diseases. Up to now, one key effort has been the study of the biliopancreatic system. In this way, numerous scientific studies were able to establish magnetic resonance imaging and particularly magnetic resonance cholangiopancreaticography (MRCP) in routine gastroenterological diagnostics [20-22]. Further innovations were achieved in the diagnosis of the small intestine, particularly in chronic inflammatory intestinal diseases [23, 24].

In October 2002, an additional, latest generation magnetic resonance imaging system (MAGNETOM Sonata, Maestro Class, Siemens Medical Solutions) went into operation at the Ludwigshafen teaching hospital, with the latest in coil technology and most up-to-date post-processing capabilities (LEONARDO workstation, Siemens Medical Solutions). While our innovative cooperation between gastroenterologists and radiologists had in the past centered primarily on the diagnosis of the biliopancreatic system and small intestine, we can now expand the cooperation and experience that developed over the years to the diagnosis of the large intestine with virtual secondary reconstruction procedures, and thereby verify the importance of noninvasive MR colonography and develop it further. It is in this context that we began a prospective study in November 2002 entitled "Prospective Comparison of MR Colonography with Conventional Colonoscopy in the Diagnosis of Colorectal Lesions".

### Study design

The study is monocentric in design, with 200 patients for whom a colonoscopy had been indicated. Magnetic resonance imaging and

conventional colonoscopy are performed in all patients within one day, after appropriate intestinal cleansing. Table 1 lists the inclusion and exclusion criteria.

The primary objective of the study is to run a prospective comparison between MR colonography and conventional colonoscopy in the detection of colorectal lesions. The goal here is to determine whether MR colonography, with the technology available today, reaches the gold standard of conventional colonoscopy in the diagnosis of colorectal lesions.

Other study objectives are to compare both methods in terms of patient acceptance and satisfaction, and to attempt to differentiate between the various stages of adenoma with respect to size and dignity as compared to the macroscopic findings and histology.

Before the planned colonoscopy, the patient undergoes an MR colonography after submitting a consent form in writing. The two examinations are performed and diagnostically evaluated independently of each other by experienced radiologists and gastroenterologists.

## MR colonography

After a complete intestinal cleansing the day before and an overnight fasting period, the MR colonography is initially performed on the day of the examination using the latest generation of our 1.5 Tesla full body MRI (MAGNETOM Sonata, Siemens Medical Solutions). A thin intestinal tube is inserted after rectal palpation. After having assumed a supine position, the patient is conveyed into the diagnostic system, and the intestine is filled with 1.5-2 liters of lukewarm water through the indwelling rectal probe. This enables a good contrasting of the intestinal lumen. Normal dosis of antiperistalsis medicine is then intravenously administered to relax the intestine. Complete filling of the large intestine and distension are then monitored via real-time acquisition of fast gradient echo images by means of a TrueFISP sequence.

After sufficient intestinal distension has been achieved with intraluminal water, transverse and coronal TrueFISP sequences and a 3D VIBE sequence are initially generated natively. Standard dosis of MR contrast material are then intravenously administered. The 3D VIBE sequence is then repeated at 75 and 90 seconds after contrast media application.

3D VIBE stands for "Volumetric Interpolated Breath-hold Examination", and is a 3D, ultra-fast gradient echo sequence with an isotropic resolution. The k-space scan is typically performed asymmetrically in this sequence, which reduces the number of phase encoding steps in the slice-selection direction. A frequency-selective fat saturation pulse is transmitted before each partition loop. To achieve a homogeneous fat saturation in the process, centric phase encoding is used in the partition direction (Fig. 1). 3D VIBE offers a complete three-dimensional anatomical coverage within a short overall measurement time.

The 3D VIBE sequence is executed with the following parameters:
TR = 3.1 ms, TE = 1.17 ms,
Flip angle = 10 degrees, 72 partitions in one breath in less than 24 seconds,
FoV = 400 mm, slice thickness = 1.5 mm.

For purposes of efficient evaluation, a dedicated colon post-processing application on a LEONARDO workstation (Siemens, Medical Solutions) automatically calculates MPRs (multiplanar reconstructions) from this three-dimensional data set in a transverse and coronal plane, as well as a survey image of the colon and the spatial display as a virtual colonoscopy (Fig. 2). In so doing, the colon post-processing application supports the two conventional examination techniques, scrolling through 3 D data sets and an interactive fly through with complete, automatic real-time navigation. A starting point can be determined to initiate the virtual flight at any location desired. The ongoing flight in the intestinal segments can be visualized at any time by updating the MPRs online and plotting the flight path in the survey image. Later in the process, the virtual colonograph and survey image are used for hardcopy documentation. In addition, the software offers all functions necessary for an up-to-date evaluation of the findings (including a summary report). The entire evaluation process only takes approx. 10 min.

## Initial experiences

We can already infer a first, positive result from present experience with MR colonography at the Ludwigshafen teaching hospital. In the 18 examined patients, MR colonography could be performed without complications, and with a high patient acceptance rate. A diagnostic evaluation of images was possible in each case. In a few examinations, however, the entire colon could not be displayed with a high-performance gradient system and a field of view of 40 cm. As a result, a complete "virtual flight" through the entire colon could not be achieved in all patients, but a detailed evaluation was always possible. Due to the low number of patients and prospective nature of the study introduced above, we are currently still working on a detailed

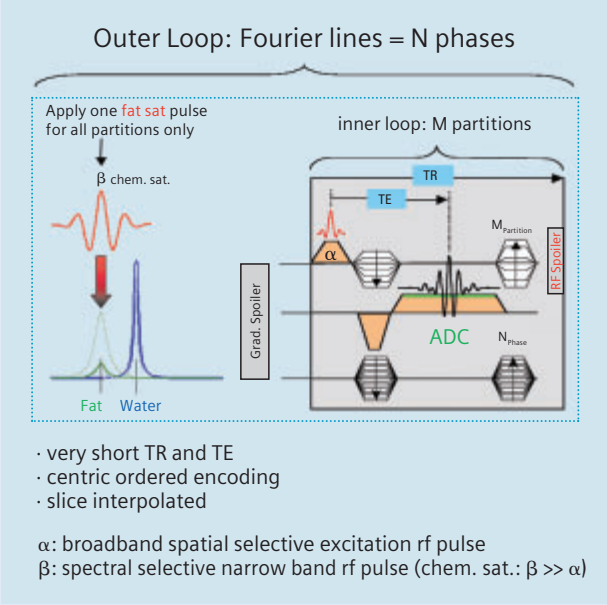
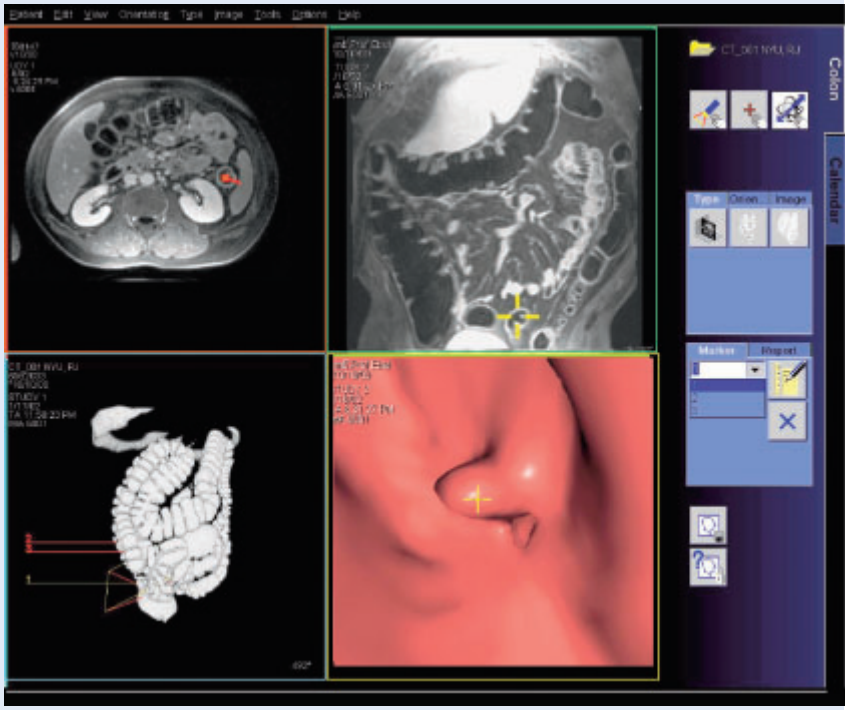



**Figure 1** *3D VIBE sequence (Siemens Medical Solutions).*

**Figure 2** *Leonardo evaluation software (Workstation, Siemens Medical Solutions).*




evaluation of the results in comparison to colonoscopy.

Figs. 3 and 4 show two impressive examples of what MR colonography is capable of doing. Fig. 3 shows a broad-based polyp in a patient who presented for further diagnosis based on a positive occult blood test. The polyp could be diagnosed with both MR colonography and colonoscopy and removed in the course of endoscopy. Fig. 4 shows an MR colonography image in comparison to a conventional colonoscopy in a patient with known ulcerative colitis. The pseudopolyps typical for the disease can be detected with both methods.

## Summary and outlook

MR colonography is a new diagnostic procedure that makes it possible to noninvasively visualize the entire large intestine without exposure to radiation. However, thus far only a small number of comparative studies have contrasted MR colonography with the gold standard, colonoscopy. The Ludwigshafen MR colonography project, a cooperation of radiologists and gastroenterologists, is aimed at this evaluation. We are convinced that close cooperation between partners is the only way to successfully pursue those projects in which the expertise of both specialties is indispensable. Neither radiologists nor gastroenterologists are currently in a position to set up objective and acceptable studies on this issue by themselves.

The possibility of using noninvasive MRI in the prevention of colorectal carcinoma can only be discussed after these kinds of prospective studies. This use may facilitate the acceptance of preventive screening for colorectal carcinoma without exposing patients to high levels of

radiation, as opposed to computerized tomography.

The objective would not necessarily be to compete with colonoscopy as the diagnostic gold standard, but rather to offer patients another screening option. Given that only about one fourth of all eligible patients avail themselves to colonoscopy screening, MR colonography could play an important role in the preventive screening concept for colorectal carcinoma alongside the test for occult blood, clinical and digital rectal examinations, and endoscopic procedures.

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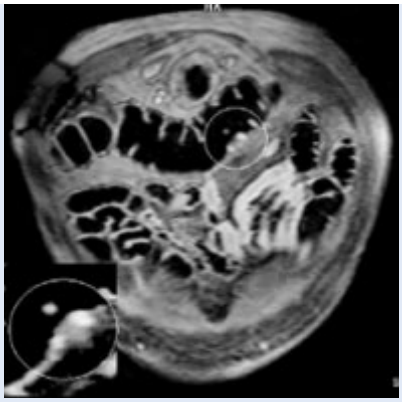
## Tables and figures

| Inclusion Criteria |
|---|
| → ***Patients over 18*** |
| → ***Colonoscopy indicated*** |
| → ***Good health*** |
| → ***Written declaration of consent from patient*** |
| **Exclusion Criteria** |
| → ***Patients under 18*** |
| → ***Known intolerance to MR contrast media*** |
| → ***Known MR contraindications, e.g., pacemakers, intracorporeal metal parts, claustrophobia*** |
| → ***Pregnant or breast-feeding patients*** |

**Table 1** *Inclusion and exclusion criteria.*



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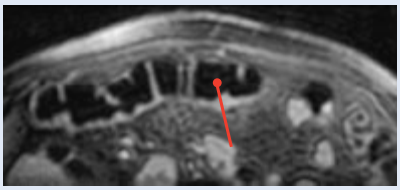

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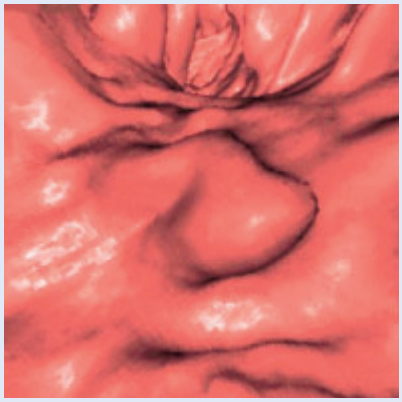

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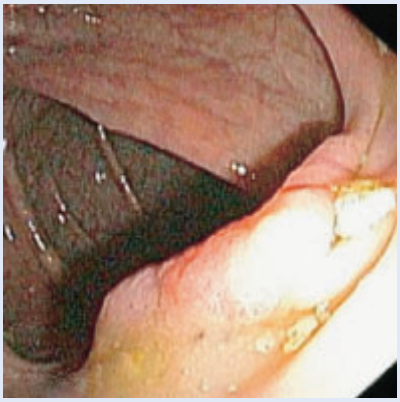


3d

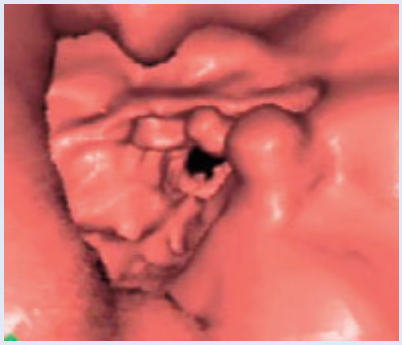
**Figure 3** *Broad-based polyp of the transverse colon.*

*a) Coronal 3D VIBE sequence*

*b) Transverse reconstruction*

*c) 3D reconstruction*

*d) Endoscopic image*



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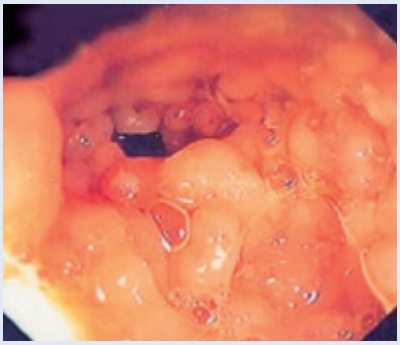

4b

**Figure 4** *Pseudopolyps in a 45 year old male patient with known ulcerative colitis.*

*a) 3D reconstruction*

*b) Endoscopic image*

# Cerebrospinal Fluid Flow Measurements – Initial Results at 3.0 T

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## Abstract

Cerebrospinal fluid (CSF) flow and production can be measured using MR velocity mapping in the cerebral aqueduct. Limited spatial resolution may, however, lead to partial volume errors which – at the cost of signal-to-noise – can be reduced by increased in-plane resolution. We assessed the accuracy of high-resolution velocity mapping at 3 T by phantom verification of flow-versus-signal linearity and phase image quality and by determination of in vivo CSF flow curves in healthy volunteers. Accuracy was within 10 % and reasonable flow values were obtained in vivo. We conclude that high-resolution CSF flow measurements can be made at 3 T.

## Introduction

Magnetic resonance (MR) velocity mapping, utilizing velocity sensitized/non sensitized gradient echo sequence pairs [1, 2], is a well-established technique for non-invasive flow quantification. Advantages of this method are that it enables quantification of velocity as well as flow and that – although limited by the capacity of the gradient system of the scanner – it has a very large dynamic range [1-3]. For studies of the cerebrospinal fluid flow circulation, which requires velocity encoding (VENC) values around 10-20 cm/s, several specific velocity mapping strategies have been proposed [4-8].

Methodological drawbacks for the study of slow flow in narrow channels include limitations caused by the relationship between object (vessel/channel) size and volume element (voxel) size [9], however several techniques have been proposed for correction of partial volume errors [10-14]. General methodological limitations also include influence on the background phase in the subtracted phase map from gradient eddy currents and Maxwell or concomitant gradients [15].

The establishment of magnetic field strengths above 2.0 T for clinical MRI is in progress, and several reports have described the use of 3.0 T for neuro MRA applications [16-17]. Potentially, the intrinsic higher signal-to-noise ratio at this field strength compared to 1.5 T could also be used to increase spatial resolution in velocity mapping of flow in narrow channels [18]. However, the accuracy of the velocity mapping technique for 3.0 T MRI units using powerful gradient systems has not yet been evaluated thoroughly.

In this preliminary study, we therefore assessed the accuracy of high-resolution gradient-echo (GRE) velocity mapping sequences at 3.0 T by phantom verification of flow-versus-signal linearity and phase image quality and by determination of in vivo CSF flow curves in healthy volunteers.

## Materials and methods

Throughout the study, a Siemens MAGNETOM Allegra 3.0 T was used. Phase variations in a stationary cylindrical phantom with 155 mm diameter, provided by the manufacturer, was studied at 3.0 T as function of axial slice position, shifted stepwise in the range 0 (magnet center) to 50 mm from the magnet center in the feet direction. The imaging slice was oblique with angulation typical for flow measurements in the cerebral aqueduct (transverse > coronal 20°). A GRE velocity mapping pulse sequence was used (VENC 20 cm/s, FOV 200, matrix 512, in-plane resolution 0.39x0.39 mm, slice thickness 7 mm, TE 8 ms, TR 100 ms, FA 15°, BW 257 Hz/pix).

Flow accuracy for different VENC values was measured quantitatively at 3.0 T using a tube phantom consisting of an outer cylinder filled with stationary tap water surrounding two tubes with tube diameter 4.8 mm, area 18.1 $mm^2$ and wall size ≤ 0.1 mm. In a first experiment, three different VENCs (5, 10 and 20 cm/s) were studied in the flow range 0-0.4 ml/s in a transverse slice positioned in the center of the magnet (FOV 100 mm, matrix 256, in-plane resolution 0.39x0.39 mm, slice thickness 10 mm, TE 11 ms, TR 100 ms, FA 30°, BW 130 Hz/pix). In a second experiment, VENC 20 cm/s was chosen to study the flow range 0-2 ml/s in transverse slices at two different slice positions, 0 (magnet center) and 40

mm from the magnet center in the feet direction (FOV 100, matrix 256, in-plane resolution 0.39x0.39 mm, slice thickness 7 mm, TE 8 ms, TR 100 ms, FA 15°, BW 257 Hz/pix).

In one healthy volunteer, a crude comparison of SNR at 3.0 T and 1.5 T (Siemens MAGNETOM Vision) was made in modulus images in an imaging slice covering the cerebral aqueduct. Images were acquired with a GRE PC-MRA sequence at 3.0 T and a GRE velocity mapping sequence at 1.5 T, using identical imaging parameters (VENC 10 cm/s, FOV 230 mm, matrix 512, in-plane resolution 0.45x0.45 mm, slice thickness 5 mm, TE 12 ms, TR 100 ms, FA 30°, BW 78 Hz/pix). For each system, the standard head-coil was used and no corrections for variations in coil performance between the systems were made in this comparison.

Finally, CSF flow through the cerebral aqueduct was measured at 3.0 T using a GRE velocity mapping sequence in two healthy volunteers (VENC 20 cm/s, FOV 200-220 mm, 6/8 rectangular FOV in the phase (L-R) direction, matrix 512, in-plane resolution 0.39x0.39-0.43x0.43 mm, slice thickness 7 mm, TE 12 ms, TR 46-50 ms, FA 30°, BW 78 Hz/pix, prospective ECG triggering).

Phase variations in the stationary phantom were studied in five regions-of-interest (ROIs) with 4.9 $cm^2$ area, placed centrally (1 ROI) and along the vertical and horizontal axis approximately 2 cm from the phantom edge (4 ROIs).

In vitro, flow evaluation was made using ROI tools available in the 3.0 T scanner software and ROI sizes were adjusted to be similar to the nominal tube size [13]. In vivo, the cerebral aqueduct region was delineated and flow was calculated using a specially designed flow evaluation program (Context Vision RadGop, Linköping, Sweden). In both cases, background ROIs were selected to correct for non-zero phase background.

## Results

Phase variations in the stationary phantom as function of axial position are shown in figure 1. In this figure, average phase in each ROI is given in percent of the maximum phase value corresponding to the VENC (+ 4096). As seen from the figure, observed phase values were between 0 and 5 % of the maximum phase value.

In the flow phantom, phase image quality was high (Fig. 2). The average measurement inaccuracy [100*abs (measured flow – nominal flow)/ nominal flow] for all VENC values in the flow range 0.05-0.4 ml/s was approximately 10 % and the linearity between flow values measured with MR and nominal flow (measured with stop-clock and measuring glass) was good (r>0.998). In fig. 3, flow measured using MR is plotted versus nominal flow for a 40 mm axial slice shift in the feet direction using VENC 20 cm/s.

In vivo (Fig. 4), we obtained SNR ratios (3. T/1.5 T) in modulus images of 1.55 (stationary tissue) and 1.64 (aqueduct). The result of flow measurements in two healthy volunteers are shown in fig. 5, and the measured peak caudal flow values in the cerebral aqueduct were 9.5 and 15.8 ml/min, respectively.

## Discussion

In this study, CSF velocity mapping was performed at 3.0 T. Using the high intrinsic SNR at this field strength, high in-plane resolution (0.39x0.39 – 0.43x0.43 $mm^2$) was obtained and CSF flow values were of reasonable order compared to earlier studies at lower field strengths

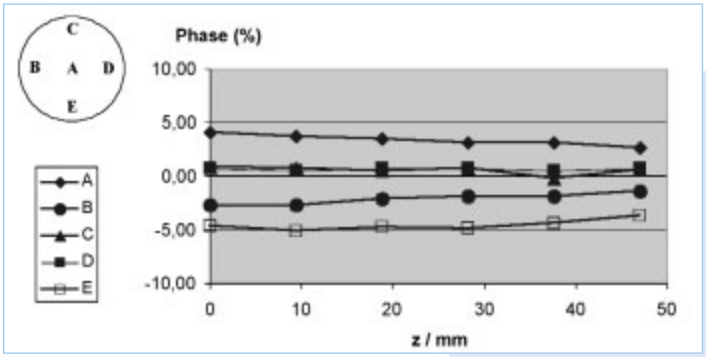



**Figure 1** *Phase variations in the stationary phantom as function of axial position (z) for a slice angulated 20° from the transverse to the coronal plane. Shifting of the slice position from the origin was made in the feet direction. Average phase in each ROI A-E is given in percent of the maximum phase value (+ 4096) and the position of each ROI is indicated (upper left).*

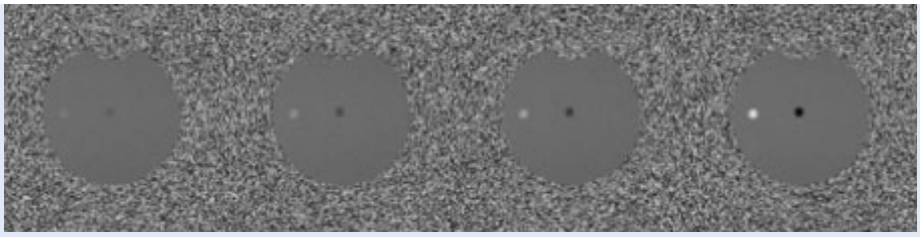
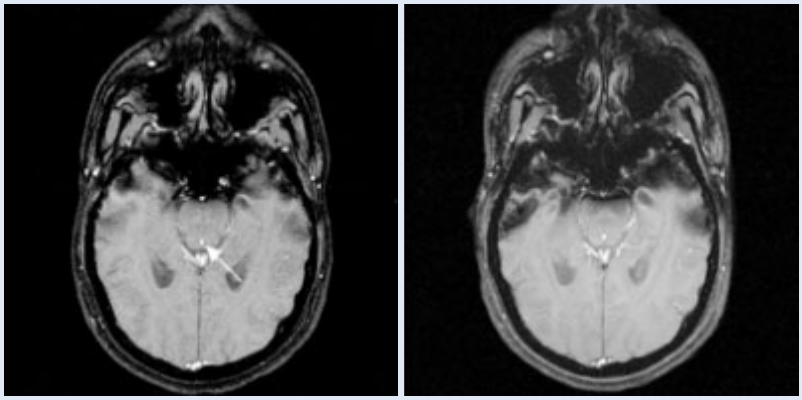


**Figure 2** *Flow phantom images in two tubes with oppositely directed flow in the range 0-0.4 ml/s obtained using VENC5, increasing velocities in images from left to right (FOV 100 mm, matrix 256, in-plane resolution 0.39x0.39 mm, slice thickness 10 mm, TE 11 ms, TR 100 ms, FA 30°, BW 130 Hz/pix).*

**Figure 3** *Flow (MR) versus flow (stop-clock and measuring glass) for a transversal slice positioned at z = 40 mm in the feet direction (FOV 100, matrix 256, in-plane resolution 0.39x0.39 mm, slice thickness 7 mm, TE 8 ms, TR 100 ms, FA 15°, BW 257 hz/pix). For the slice position z = 0 mm, a similar linearity was observed (y = 0.91x + 0.067, R2 = 0.998).*



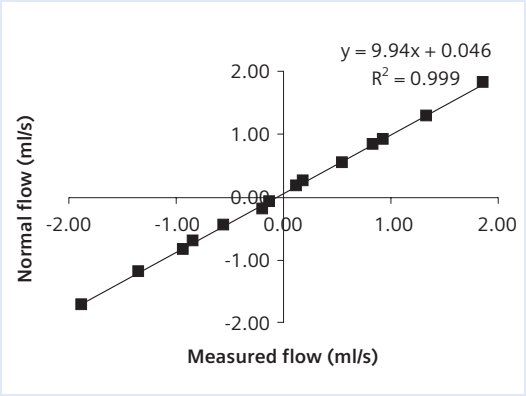



**Figure 4** *GRE modulus images of the same volunteer with similar positioning of the image slice at 1.5 T (velocity mapping sequence, left) and 3 T (PC MRA sequence, right). Note increased susceptibility artefacts from the sphenoid sinus and the petrous bones but also visible SNR increase, at 3 T as compared to 1.5 T. In the cerebral aqueduct (arrow indicating central bright area) CSF appears white due to inflow enhancement.*

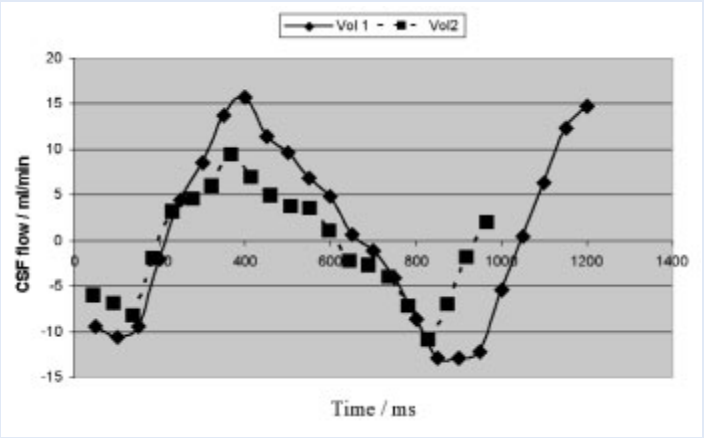



**Figure 5** *CSF flow curves for two healthy volunteers obtained at 3.0 T.*

[5, 8, 19]. The phase background varied with in-plane position, indicating influence from a combination of eddy currents and concomitant gradients, although no major variations were seen as function of axial position in the slice shift range chosen in this study. We used a very simple phase correction routine (subtraction of adjacent stationary background values) both in vitro and in vivo, although it can not be ruled out that more sophisticated correction methods [20, 21] addressing each potential phase error component separately will be necessary in precise studies of e.g. CSF production rates and/or flow studies in image positions significantly displaced from the magnet origin.

Potential clinical applications are, for example, determination of CSF flow and production in patients with hydrocephalus and flow studies in non-magnetic CSF shunts.

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# Intracranial 3D ToF MRA with Parallel Acquisition Techniques at 1.5 T and 3.0 T

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## Introduction

Magnetic resonance angiography (MRA) has undergone significant developments over the past decade. Time-of-flight (ToF) MRA sequences have been widely used for imaging intracranial vessels. With this technique the vessels give high signal intensity related to the inflow effect of blood during its passage through the acquisition volume, whereas the background tissue appears dark because a short repetition time prevents relaxation of stationary tissue.

Currently available pulse sequences are well optimized for ToF MRA at 1.5 T. However, one of the principal limitations inherent to ToF MRA is that they remain signal-limited when pushed to the limits of higher resolution and shorter acquisition times.

The main advantage of high B-field imaging is a significant improvement in the signal-to-noise-ratio (SNR), which increases in an approximately linear fashion with field strength in the range of 1.5 T to 3.0 T. ToF MRA is a technique that can benefit from the increased S/N available at 3.0 T by decreasing voxel size resulting in improved spatial resolution compared to 1.5 T. In addition, advances in coil technology, such as circularly polarized coils, have resulted in further signal gains and multi-channel technology has allowed for novel acquisition strategies such as integrated Parallel Acquisition Techniques (iPAT).

We report on our preliminary results comparing intracranial 3D ToF MRA with iPAT at 1.5 T and 3.0 T.

## Material and methods

Intracranial 3D ToF MRA with iPAT was performed at 1.5 T (MAGNETOM Sonata) and 3.0 T (MAGNETOM Trio) whole body systems equipped with identical state-of-the-art gradient sets (40 mT/m maximum, 200 mT/m/s slew rate) and similarly designed 8-channel phased array head coils. For the iPAT-supported MRA techniques, the GRAPPA (GeneRalized Autocalibrating Partially Parallel Acquisition) reconstruction algorithm has been implemented. The acceleration factor was set to 2. To obtain a fair comparison between 1.5 T and 3.0 T, each sequence was optimized for a total imaging time of approximately 7.35 and 7.15 minutes, respectively. Imaging matrices were 512/640 (phase/read) at 3.0 T and 486/512 (phase/read) at 1.5 T resulting in voxel sizes of 0.08 $mm^3$ and 0.13 $mm^3$, repectively.

## Results

Analysis revealed a significant increase in both the vessel SNR and CNR at 3.0 T. Overall vessel visualization was significantly better at 3.0 T. In particular, visualization of smaller vessel segments such as M3 and P3 segments as well as delination of PICA and AICA was superior compared with 3D ToF MRA at 1.5 T (Fig. 1).

Delineation of a left temporal AVM in one patient was slightly better at 3.0 T (Fig. 2). One aneurysm of the right MCA with a size of 2.8 mm was reliably detected only at 3.0 T. Wrap around artifacts in the iPAT supported 3D ToF MRAs were minor at both field strengths and had no noticeable influence on image analysis. The increased susceptibility effects at 3.0 T, especially at air-bone interfaces along the floor of the anterior cranial fossa and adjacent to the petrous portions of the temporal bones had no side effects on the image quality of ToF MRA at 3.0 T.

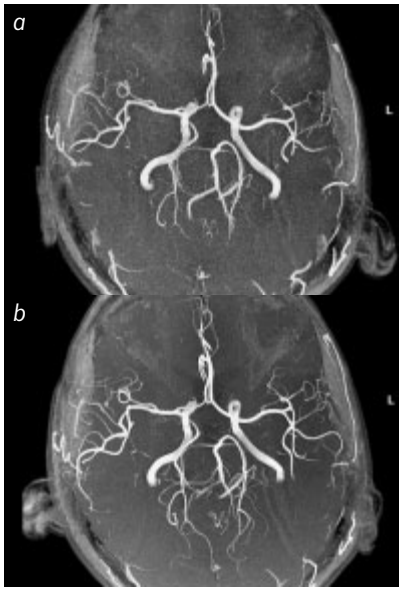


**Figure 1** *Axial 3D ToF MIP images at 1.5 T (a) and 3.0 T (b). Note the better visualization of distal MCA and PCA branches as well as the right AICA at 3.0 T. Minor aliasing artifacts are noticed due to the use of the iPAT reconstruction algorithm.*

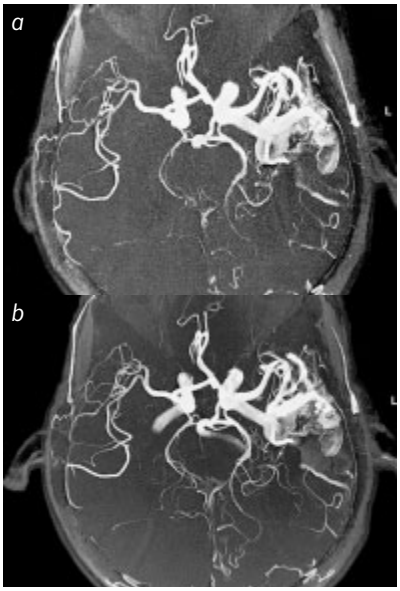


**Figure 2** *Axial collapse 3D ToF MIP images at 1.5 T (a) and 3.0 T (b). The large left temporal AVM is slightly better delineated at 3.0 T. However, delineation of the distal MCA and PCA branches is far superior at 3.0 T.*

## Discussion

ToF MRA is commonly used for the evaluation of intracranial vascular pathology. Currently available pulse sequences are well optimized for ToF MRA at 1.5 T. However, one of the principal limitations inherent to ToF MRA is that they remain signal-limited when pushed to the limits of higher resolution and shorter acquisition times.

In 1998 the FDA granted clearance for the use of clinical MR imaging at main magnetic field strengths of up to 4.0 T. Prior to this approval, imaging with main magnetic field strengths greater than 1.5 T was primarily reserved for investigational use and research applications. Previous studies have already demonstrated improvements in image quality of ToF MRA at 3.0 T (1, 2). However, they did not use state-of-the-art gradient systems and the potential benefits of using multi-phased array coil technology in conjunction with parallel acquisition methods has not been investigated.

There are various factors which enhance the overall image quality in ToF-MRA at 3.0 T compared with MRA at lower field strengths. The increased SNR available at 3.0 T was used in our study to increase spatial resolution, thereby reducing the amount of partial volume artifact. Smaller voxels are less subject to intravoxel dephasing because they contain a smaller heterogeneity of spins, providing further improvements in MRA. In addition, the effects of magnetic field strength-related T1-lengthening of brain parenchyma and background tissue are beneficial for ToF MRA at 3.0 T, providing better suppression of background signal.

The main applications of iPAT are the reduction of examination time by faster imaging or the increase of spatial resolution in a given acquisition time. However, the trade-off for reducing the number of acquired k-space lines using iPAT is a decreased SNR. Due to this loss of SNR, parallel acquisition techniques are particularly useful when the corresponding image has a high intrinsic SNR, such as in 3D ToF MRA at 3.0 T. On the other hand, implemetation of iPAT at 1.5 T might have a negative effect on image quality due to the limited SNR.

Several techniques have been suggested for the iPAT image reconstruction from the reduced data sets. They can be divided into two different groups such as techniques working on the data in frequency domain (SMASH, GRAPPA) and techniques working on the Fourier transformed data in the image domain (SENSE). However, one general limitation of the iPAT approach is the propagation of wrap-around artifacts into the center of the image. We therefore decided to use an AUTO-SMASH like algorithm such as GRAPPA since these artifacts are less prominent compared with the SENSE technique. In our study aliasing artifacts were only mild and therefore did not limit the accurate assessment of fine vessel detail.

In conclusion, we have demonstrated the superiority of iPAT supported 3D ToF MRA at 3.0 T compared with 1.5 T. The combined used of a multi-channel phased-array head coil in conjunction with iPAT allows for high resolution intracranial vessel imaging with adequate SNR in reasonable imaging times. With continued optimization and refinements, 3D ToF MRA at 3.0 T will further reduce the need for conventional digital subtraction angiography, which is still an invasive method with possible serious complications.

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# High Workflow of Maestro Class System at a Brazilian Clinic

By: Alessandra Wasilenko for
Siemens Medical Solutions Brazil

## 49 MRI exams per day – from head to toe

The Multi-Imagem clinic is located in a large 500 square meter mansion in Ipanema, the romantic neighborhood in the southern part of Rio de Janeiro. The city of Rio appears in some of Brazil's most picturesque postcards, in addition to being serenaded in some of the most renowned bossa nova song lyrics and poems. Attractive and historical lines also give style to the clinic's architecture. This is the former residence of the Jaguaripe Baron during Brazil's imperial period and which, less than one year ago, leased space to one of the most important magnetic resonance clinics in the country. Inaugurated in October of 2002, the spacious, well built, comfortable, clean design and cozy Multi-Imagem Ipanema looks like anything but a clinic (Fig. 1).

This is the perfect location for the first MAGNETOM Symphony Maestro Class system from Dr. Romeu Côrtes Domingues' network of clinics. "We decided that a machine such as this had to be installed in the city's most exclusive region; to be adopted by opinion leading doctors and installed in their offices. (...) It was not easy to find a house that would allow structuring a magnetic resonance clinic with its peculiarities (...), it was like finding a needle in a haystack.
A house located in one of the best neighborhoods in town, on a pleasant street lined with trees, located between the Rodrigo de Freitas Lake and Ipanema, one of Brazil's most famous beaches" (Fig. 2).


Figure 1

"Combining a comfortable clinic and well trained people with quick and well executed exams, using the best resonance machine there is in Rio de Janeiro, are just some of the competitive advantages that contribute to the clinic's success", said Dr. Romeu Domingues when guiding us round the interior of the clinic (Fig. 3).

The Multi-Imagem clinic performs an average of 40 to 45 examinations per day. The last milestone, recorded recently, was a total of 49 exams in a single day. That amounts to almost more than one thousand procedures in a one month period. An outstanding figure when taking into account that the majority of the exams performed are complex, including spectroscopy, perfusion and diffusion. "In Rio de Janeiro, we are the only clinic that does brain tractography, bidimensional myocardial perfusion and three-dimensional spectroscopy of the

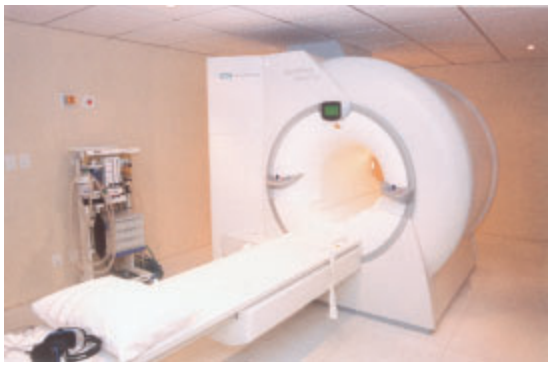


Figure 2

Figure 3

prostate. We are also one of the few groups in Brazil that conducts cardiac and cerebral functional studies", (Figs. 4, 5, 6, 7) he says. Our examinations are even more comprehensive because, since May, the clinic received the work-in-progress software for Diffusion Tensor* and now offers diffusion tensor and tractography images. "In spite of our daily agenda of 40 exams per day, our neuro-radiological exams are complete, regardless of whether the doctor prescribed them", he says. In Latin America, the intention of the pioneers is to test the software, conduct scientific studies about white substance diseases in the brain and present results at congresses. The Diffusion Tensor* was developed in partnership with Harvard University in Boston. "We are going to provide feedback to professors in Boston and to Siemens' specialists in Germany. We already have projects associated to multiple sclerosis, brain tumors and Alzheimer's disease. We are testing the software on patients that suffer from these three pathologies", affirms the radiologist.

## Advantages of MAGNETOM Symphony for workflow gains

Dr. Domingues points out two advantages that make this equipment quicker, more efficient and ensures productivity gains: integrated panoramic array coils and no need for pre-scanning.

The integrated coils represent a major advantage since they allow the performance of more than one exam at a time without having to move the patient. "For example, in an abdomen and pelvis examination, we no longer have to put the patient on the table, perform the abdomen exam, then take him off to position the coil on the pelvis and then put the patient back on the table. We simply put the abdomen and pelvis coil and, without moving the patient, perform the two exams. The same occurs with brain and spine exams. This way, the clinic no longer needs to schedule two appointments, since we can do both in a single session and save a lot of time. At times, I can schedule up to three exams in a single appointment. With this, the patient also saves a lot of time, not having to return to the clinic and undergo the entire procedure again".

Another feature that has made exams very quick, including conventional exams, is that between one sequence and another, there is no longer the need to pre-scan. Siemens has eliminated pre-scanning, which is something that the competition does not yet offer. "We go from one sequence that lasts a little over 60 seconds to another without losing any time. In previous versions, the system required some time to perform adjustment and calibration between one sequence and another. With MAGNETOM Symphony, this is all done automatically".

## Differentials adopted at Multi-Imagem

The clinic, which is open from 6:45 a.m. to 11:00 p.m., has 30 employees divided into three work shifts. The medical staff is composed of six physicians, three fellows and eight technicians. A nurse receives the

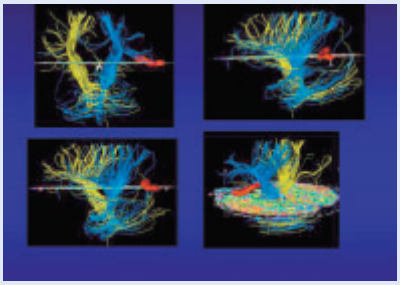


Figure 4

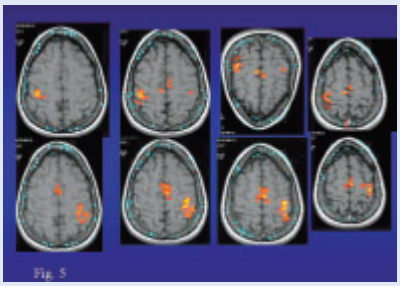


Figure 5

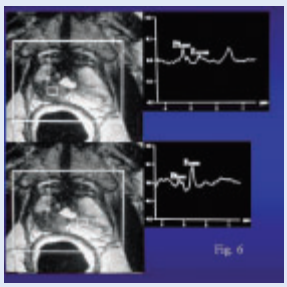


Figure 6

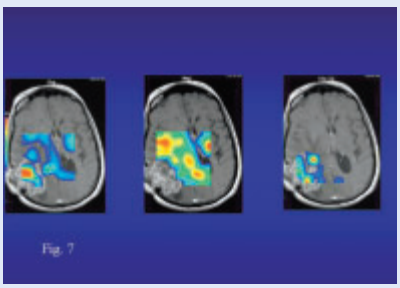


Figure 7

** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

Figure 8

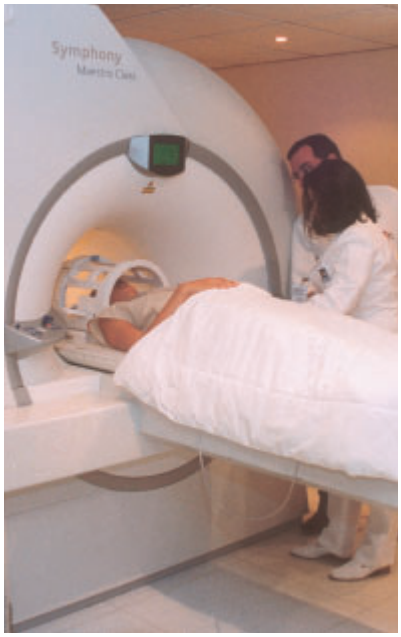
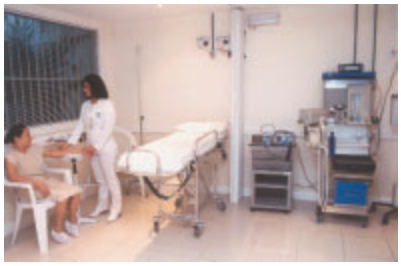



Figure 9

Figure 10



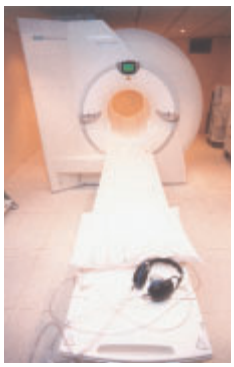


Figure 11

patient; instructs him or her to change clothes; get his or her vein access, whenever necessary; sends the person into the room; and positions him or her on the examination table. The resident is responsible for talking to the patient, writing down the anamneses and collecting prior relevant examinations. One radiologist is responsible for monitoring the exam and conducting post processing procedures on the Leonardo workstation; the other radiologist is responsible for the exam report or review. "Many complex procedures, such as angiography, cardio, functional neurological and prostate spectroscopy examinations require post processing. For this reason, we always need two doctors per shift" (Fig. 8).

Patients are instructed to arrive half an hour in advance. "When the time comes for the patient to enter the examination room, we have already talked to this person, analyzed his or her previous exams and, whenever necessary, punctured the vein. At present, we cannot waste any time. The fee charged per exam is very low and, in order to continue investing, we need to be highly productive. The examination in Brazil ranks among the cheapest in the world, so we have to do a lot of them, quickly and with quality", says Dr. Domingues (Fig. 9).

The clinic possesses two anesthesia machines. One in the MRI room; the second in the anesthesia recovery room's nursing center. Anesthetic induction on patients that require such procedure – such as patients with claustrophobia, in coma, in severe pain or children– is done outside the magnet room and always with two anesthesiologists and one nurse. When one examination is ending, the next patient is already under anesthesia. Once the exam is completed, the patient's recovery also occurs outside the exam room, in the nursing center. Dr Domingues explains: "The patient does not need to be anesthetized and recover inside the resonance room, since this procedure takes some time. In the past, we used to schedule one hour for the exam, since 20 minutes were spent with induction and another 10 with recovery. By carrying out these steps in the nursing center, we gain an average of 30 minutes". The procedure adopted at Multi-Imagem was adopted by the other clinics within the network (Fig. 10).

Anamnesis, when done ahead of time, also provides for gains in various stages. One of them is discovering whether the case will require the use of contrast for the nurse to get the patient's vein before the exam begins. About 40 % of the exams performed at the clinic require vein puncturing, such as: abdominal, pelvic, angiographic, cerebral and cardiac studies.

There are three cabins for changing clothes. "While one patients is leaving, the other has already changed clothes and is all ready to go, anesthetized and vein ready, if required".

## Special advantages of MAGNETOM Symphony and Multi-Imagem for patients

The equipment is fast and has a nice design, which makes it more tolerable, especially for claustrophobic people. Dr. Domingues is proud of the new facility: "We have patients that cannot stand being submitted to exams at our other clinics that have older Siemens equipment, such as Vision, but tolerate Symphony and without anesthesia. I tell patients: 'the equipment is short, safe and very fast', and also tell them how long the exam will take. The reduction in

**Figure 12** *From left to right: Dr. Romeu Cortes Domingues and Dr. Eric Martins. Dr. Roberto Cortes Domingues and the Technicians: Isabel Cristina Madeira Barreto and Luís Antonio de Oliveira Alves*

examination time eases things. It is one thing to stay in the machine half an hour and a whole different story when we're talking about five or seven minutes. At times, I can even perform exams on children without having to anesthetize them".

The team always asks if the patient wishes to listen to some kind of music during the exam. Music helps diminish the feeling of claustrophobia and anxiety. A winter garden is within sight for patients from inside the room and from on top of the exam table, making the space more peaceful and relaxing.

## Time savers per exam

According to Dr. Domingues, with MAGNETOM Symphony, all exams – neurological; angiography; cardiac, from the simplest to the most lengthy ones, such as those involving perfusion; breast tumor recurrence; abdominal and pelvic exams of all types; cholangiographies; urological MRI and 3D spectroscopy of the prostrate exams – are quick and simple to perform. Exams that took up a lot of time, such as abdomen and MR Cholangiography, can now be performed in about 15 minutes. "Before, it took half an hour to perform a spectroscopy, even using Siemens equipment. Now, this same procedure can be done in just five minutes. It is also a lot easier to do MR Angiography examination. In the past, we had to do the bolus test and calculate the best moment when the contrast would reach the artery being analyzed. With this machine, the patient already comes in vein ready; we then do the procedure; and, simultaneously, in real time, we see the contrast arriving at the area in question, then record this sequence with a simple click. It has become a simpler and quicker exam. A procedure that took up 30 to 40 minutes can now be done in 10 to 15 minutes; from the time the patient enters and exits the examination room".

At the Multi-Imagem Ipanema clinic, spinal column, knee, shoulder and hip exams are carried out in less than 10 minutes, between 7 and 8 minutes. Simple neurological procedures take 10 to 15 minutes. Complete exams with functional techniques are done in less than half an hour. In the past, a complete brain exam would take almost one hour and now takes half the time, since the clinic performs two exams in a single appointment. A Single Voxel Spectroscopy takes only three minutes, whereas a Multi-Voxel Spectroscopy takes about five minutes and the diffusion tensor about two to three minutes.

## Profile

Dr. Romeu Côrtes Domingues studied medicine and did his residency in Radiology at the Federal University of Rio de Janeiro (UFRJ), at Hospital do Fundão. In 1989 and 1990, he did his fellowship in magnetic resonance at Harvard University's main hospital (Massachusetts General Hospital), in Boston. Upon his return to Brazil, Dr. Romeu worked four years at the Luis Felipe Matoso Clinic (RJ). In 1994, he opened his first clinic, IRM Ressonância Magnética, and his second clinic in 1995, CDPI. The third clinic, Multi-Imagem, opened in 1998. Multi-Imagem Ipanema was inaugurated in October 2002. Today, Dr. Romeu spends his time as a doctor working at Multi-Imagem and CDPI. He is also vice-president of the Brazilian college of Radiology, participates in scientific congresses, having lectured at more than 300 conferences. In 2004, he will be presenting a class at the International Radiology Congress, in Montreal, Canada.

Dr. Roberto Côrtes Domingues studied at the Federal University of Rio de Janeiro, having also done his residency at Hospital do Fundão. In 1997, he undertook an 18-month specialization course in Boston. Dr. Roberto was responsible for bringing functional neuro techniques to the state of Rio de Janeiro. In 1998, he was already performing diffusion, perfusion and spectroscopy exams using a Siemens MAGNETOM Vision.

Radiologists Dr. Romeu and Dr. Roberto Côrtes Domingues focus on internal medicine, vascular and neurological studies. A third brother, Dr. Rômulo Côrtes Domingues, also works at Multi-Imagem clinic. His focus is on musculoskeletal studies. The clinic offers all types of orthopedic exams, including MR arthrography, being a benchmark in the sports area. All athletes from Rio de Janeiro soccer teams, the national soccer team and the Brazilian Olympic Committee (COB) only undergo exams at the Multi-Imagem and CDPI clinics. The degree of confidence is attested by the Brazilian Olympic Committee's invitation to Dr. Rômulo Domingues of accompanying the Brazilian athletes in the 2003 Pan-American Games, held in the Dominican Republic.

# Bilateral Four Channel Phased Array Carotid Coil from Machnet

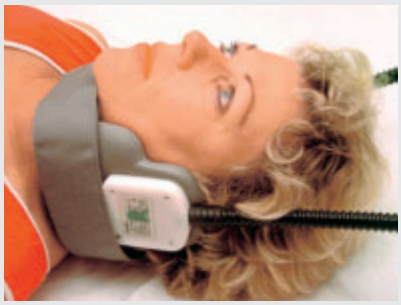
## Company Description

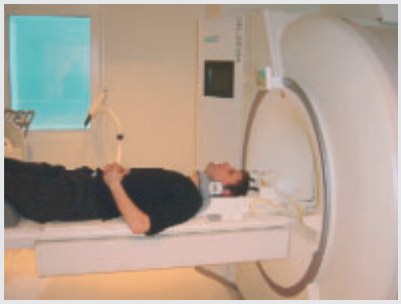
Machnet BV is one of the few suppliers who develop and produce special MRI Coils. They design, manufacture and market specialty coils for MRI all around the globe.

The main office is in Eelde, The Netherlands. For more information or questions, please contact Machnet Sales Department
+31 (0) 50 577 9846
Email address: sales@machnet.nl

## Introduction

The Phased Array Carotid Coil is a flex coil. The assembly is coated with a soft polymer foam to minimize patient discomfort. The flexibility of the coil enables it to be positioned on both sides of the neck and held in place with a soft collar.





The bilateral 4-channel phased array coil is designed for bilateral proton imaging of the carotids, and allows for sub-millimeter resolution of the carotid lumen, the vessel walls and atherosclerotic plaques. Due to its inherent contrast resolution, MRI has the potential to provide a surplus of information on the composition of the atherosclerotic plaque.

The coil provides high-resolution images with good definition of the lumen and the vessel walls, without disturbance from flow artifacts.

Note: even though the coil wasn't developed for such purposes, it has been used to scan baby hearts because of the high-resolution and the penetration depth (Fig. 5).

## Technique

The Phased Array Carotid Coil is compatible with the MAGNETOM Symphony and the MAGNETOM Sonata 1.5 T MAGNETOM scanners. All the images in this article were produced with these two types of scanners.

Magnetic resonance imaging of the carotid artery wall and in particular of carotid artery atherosclerosis, has the potential to identify patients at risk of cerebrovascular events. Magnetic resonance imaging has the ability to identify lipid and fibrotic components of complex atherosclerosis, which are important determinants for risk of complications in the coronary circulation and – some evidence suggests – the carotid circulation also. What is required is high resolution black blood imaging, with an in-plane resolution of at least 0.5x0.5 mm.

## Clinical images

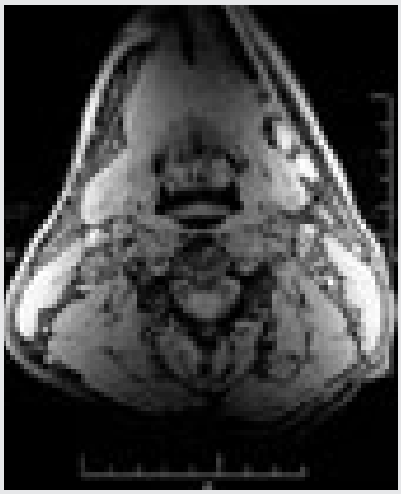


**Figure 1** *Image courtesy of Aad van der Lugt, MD, PhD, Mohamed Ouhlous, MD, Piotr Wielopolski, MD Erasmus Medical Center-Daniel den Hoed, Rotterdam.*

*Acquisition parameters:*
*TR 1976.3ms, TE = 8.6 ms.*
*FOV = 147 x 180 mm, 448x359,*
*3 mm slice thickness.*

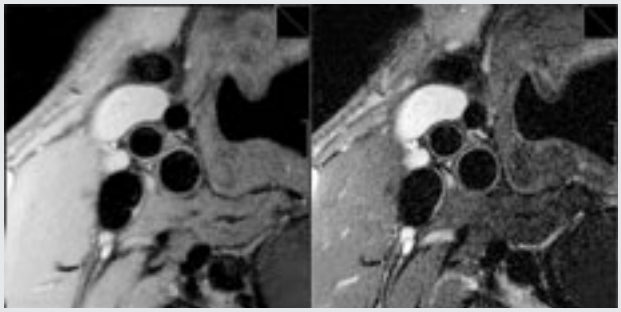


**Figure 2** *Image was performed with MAGNETOM Sonata 1.5 T Scanner. Image courtesy of Aad van der Lugt, MD, PhD, Mohamed Ouhlous, MD, Piotr Wielopolski, MD, Erasmus Medical Center-Daniel den Hoed, Rotterdam.*

*Acquisition parameters left image:*
*TR 2234.8 ms, TE = 16.0 ms. FOV = 103x120 mm, 440x512, 3 mm slice thickness.*
*Acquisition parameters right image:*
*TR 2260.5 ms, TE = 64.0 ms. FOV = 103x120 mm, 440x512, 3 mm slice thickness.*

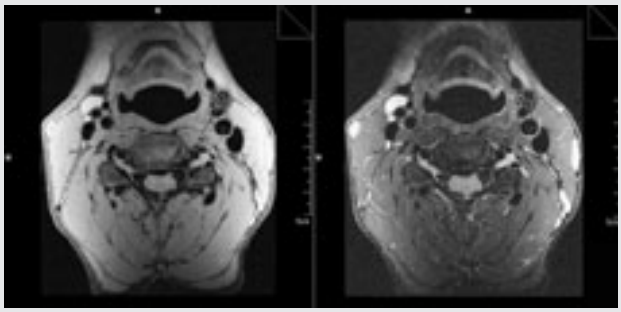


**Figure 3** *Image was performed with MAGNETOM Sonata 1.5 T Scanner. Image courtesy of Aad van der Lugt, MD, PhD, Mohamed Ouhlous, MD, Piotr Wielopolski, MD, Erasmus Medical Center-Daniel den Hoed, Rotterdam.*

*Acquistion parameters left image:*
*TR 2234.8 ms, TE = 16.0 ms. FOV = 103x120 mm, 440x512, 3 mm slice thickness.*

*Acquisition parameters right image:*
*TR 2260.5 ms, TE = 64.0 ms. FOV = 103x120 mm, 440x512, 3 mm slice thickness.*

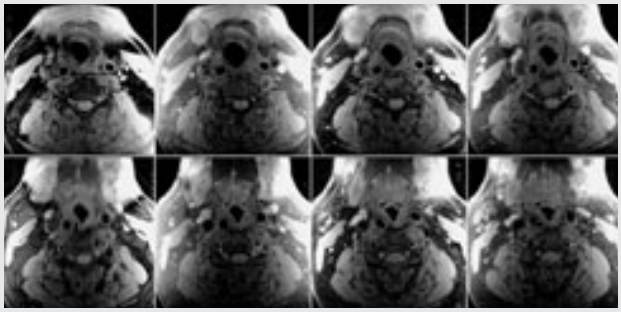


**Figure 4** *Images of a 55 year old patient with carotid plaques. Image courtesy of Dr. Zahi A. Fayad, Imaging Science Laboratories, Mount Sinai School of Medicine.*

*Acquisition parameters:*
*TR 2000 ms, TE = 5 ms, 3 mm slice thickness, 0.3 mm inter-slice distance.*
*FOV was 140x140 mm; spatial resolution of 0.54x0.54 mm.*
*Turbo factor = 11.*

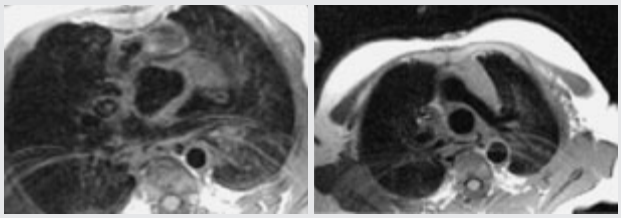


**Figure 5** *Baby Heart. Image courtesy of Dr. N. Abolmaali. J.W. Goethe Universitätsklinikum, Frankfurt.*

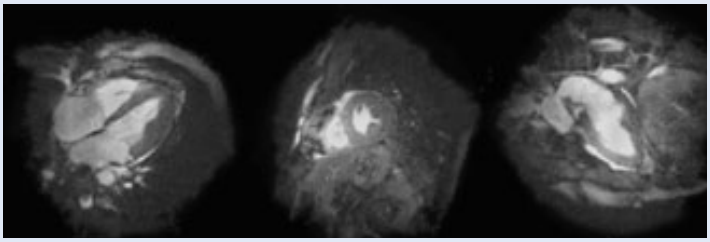
**Figure 6** *Carotid Artery Wall. Image of a 25 year old healthy male volunteer.*

*Image courtesy of Dr. Stephen Worthley, Adelaide Wakefield Hospital, Australia.*

*Acquisition parameters:*
*The images show an axial T1 weighted turbo spin echo image with a field-of-view of 11x11 cm, and 256x256 matrix and slice thickness of 3 mm. The image quality is evident and in the magnified view of the common carotid one can distinguish the normal media (high signal) from the surrounding dense adventitia (low signal).*

# Self-Gated Cardiac Cine* Virtually Eliminates ECG Triggering

Gary McNeal and Kevin Johnson
Cardiovascular MRI Team
Siemens Medical Solutions USA, Inc.



## Innovative new technology virtually eliminates ECG triggering

Siemens recently introduced Self-Gated Cardiac Cine, an innovative new technology that virtually eliminates the need to obtain an electrocardiogram (ECG) signal during cardiac magnetic resonance (CMR) imaging. One of the remaining challenges in CMR imaging is accurate and reliable synchronization of an MRI scan with the heartbeat. Although recent developments like the Siemens Optical ECG Lead System have eliminated most problems, some patients, especially at 3T, still provide challenges. This software extracts cardiac motion information from MRI data and eliminates the need for wires and electrodes to be attached to the patient, thus avoiding the difficulties of obtaining a reliable ECG signal inside the high magnetic field of an MR system. Additionally, initial results suggest that this technology may have image quality advantages over standard ECG synchronization. Siemens plans to extend the same technology to respiratory gating to eliminate the need for patient breath holding during CMR scans and to improve the reliability of coronary angiography exams.

Richard D. White, M.D., Head, Section of Cardiovascular Imaging, Division of Radiology, The Cleveland Clinic Foundation, explains: "Self-Gating makes it possible to overcome the limitations of maintaining accurate ECG signal on certain patients once and for all. There is a wireless advantage especially for patients such as those with disease of the pericardial sac or with right heart overload."

Prior to the introduction of Self-Gated Cine, the only alternative available when ECG triggering was not optimal was to use Real-Time Cine. However, with Real-Time Cine, the MRI scan suffers from low spatial resolution. Fortunately, Self-Gated Cine does not suffer from low spatial resolution because it is synchronized to the motion of the heart during six to twelve successive beats.

Figure 1 *High resolution Self-Gated Cine images in the horizontal long axis, short axis, and vertical long axis.*

## Self-Gating methods

Self-Gating methods were first described in 1988-89 (Spraggins; Hinks; Kim; Drobnitsky) and patented by Siemens in 1990 (Spraggins and Owens). The Spraggins and Owens method used an interleaved acquisition of central k-space lines for motion information (navigator echoes) and phase-encoded lines for image information. As the position of the heart changed during its beat, the amplitude of the motion navigator echo changed accordingly, thereby providing a periodic signal to be used for retrospective reconstruction of the cine images. This method suffered from 50 % inefficiency because every other line of raw data was used strictly for motion detection.

More recent methods derive cardiac and respiratory motion directly from the image data itself, with no loss of efficiency because no additional navigator echoes are required (Larson; Simonetti; Laub; White). Currently, three different methods are being used to extract cardiac motion information from the raw data lines: Echo Peak Amplitude, Center of Mass, and 2D ROI Correlation. The first method shows the most promise.

## Echo Peak Amplitude method

The Echo Peak Amplitude method of Self-Gating described by Larson et al. is a variation of the original Spraggins and Owens model, except that a radial or spiral k-space trajectory is used instead of a conventional linear trajectory. Since each line of raw data passes through the center of k-space, no additional motion navigator echoes are required, thereby making this method essentially 100% efficient. The average signal is dominated by blood pool expansion and contraction through the cardiac cycle, thereby providing a periodic signal to be used for retrospective reconstruction of the cine images.

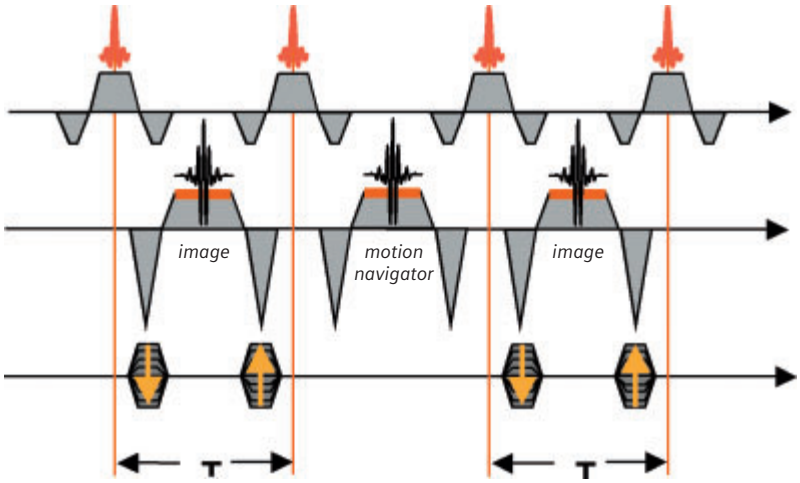
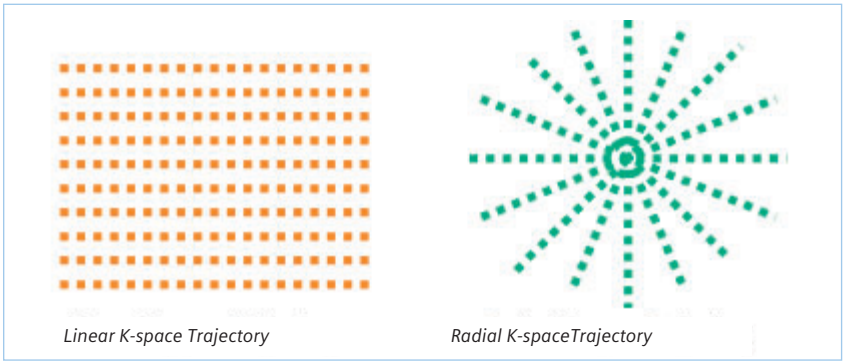


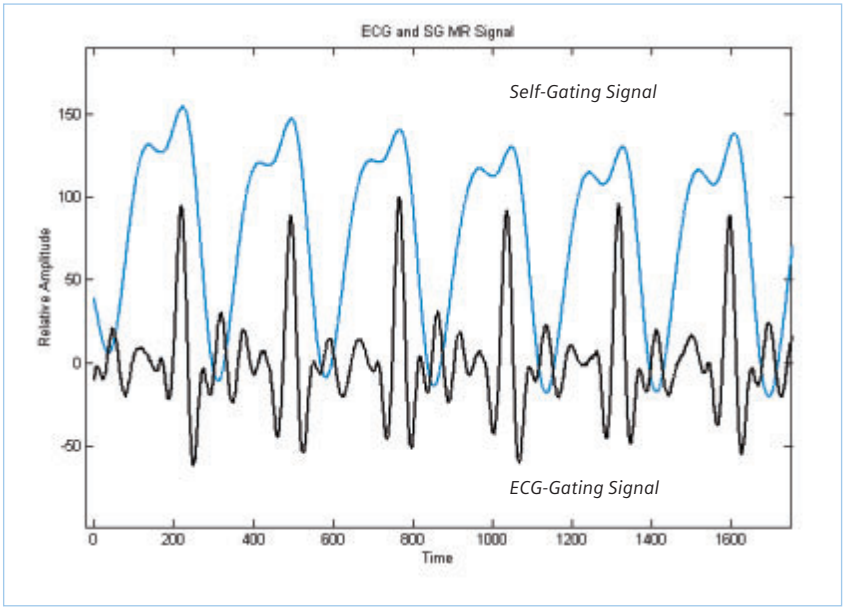

**Figure 2** *The Wireless-Gating method uses interleaved lines of image data and motion navigators, but suffers from 50 % inefficiency.*

**Figure 3** *The Echo Peak Amplitude method uses a radial trajectory to sample the center of k-space during each acquired data line. Each echo reflects the average signal in the image, which is dominated by blood pool expansion and contraction through the cardiac cycle. The echo peak signal cycles at the same rate as the ECG signal, and thus is used instead of the ECG signal.*




## Applications

Although generally applicable, early results show that in cases of arrhythmia and congenital disease gating from the mechanical motion of the heart will provide advantages over the use of ECG triggering.




** The information about this product is preliminary. The product is under development and is not commercially available in the U.S., and its future availability cannot be ensured.*

## Self-Gating clinical results: The images speak for themselves!

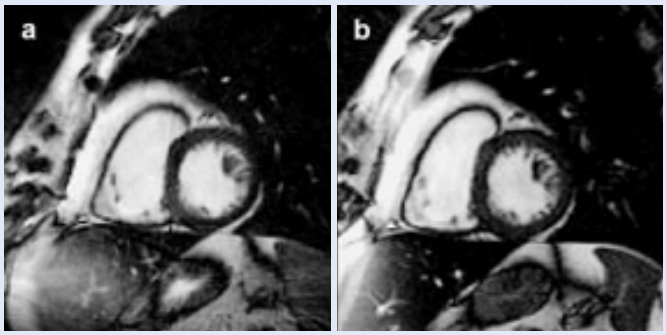



**Figure 4** *Healthy volunteer.*

*a) Self-Gated Retro Cine*

*b) ECG-Gated Retro Cine*

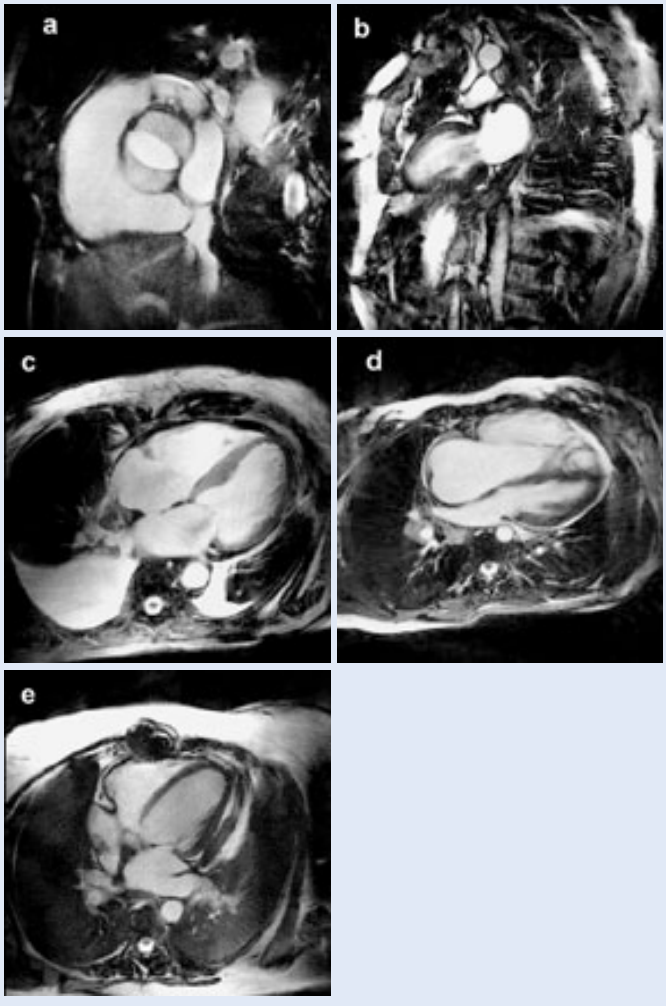



**Figure 5** *Self-Gated Cine images courtesy of Dr. Richard D. White and Dr. Arthur E. Stillman, Cleveland Clinic Foundation, Cleveland, OH.*

*a) Bicuspid aortic valve*

*b) Stenotic mitral valve*

*c) Regurgitant mitral valve*

*d) Right heart overload*

*e) Constrictive pericarditis*

# How to Improve your 3D ToF with a Few Drops of Gadolinium

J. Dehem, M.D.
Jan Yperman Hospital,
Ypres (Belgium)

G. Laureys, M.D.
MR application specialist,
Siemens Belgium

## Our main workhorse for MR angiography of the cerebral arteries is 3D ToF.

To use the full potential of our 3D ToF we need to remember a few basic principles. A high contrast between flowing blood and stationary background is achieved with a relative high flip angle and a short TR, so that stationary tissue gets saturated and only inflowing spins produce high signal, hence the name Time of Flight.

The highest possible inflow is achieved by positioning the 3D block orthogonal on the blood vessels. Since the ophthalmic artery runs orthogonal to the carotid artery (and thus parallel to the 3D block), it will not give any signal.

For even further suppression of the background signal, the sequence designers have provided us with two additional tools:

- The use of magnetization transfer (since flowing spins don't experience the MT effect and the MT effect of blood is lower than the MT effect of brain tissue) to suppress signal from water molecules in the stationary background.
- The use of water excitation pre-pulses to suppress signal from fat, e.g. orbital fat.

Since the effect of inflowing spins is used to produce a high signal in the blood vessels, the 3D block shouldn't be too thick, otherwise the inflowing spins also get saturated and signal in the blood vessels will drop. This kind of problem does not occur in 2D ToF, where you excite slice after slice.

The problem of 2D ToF, however, is that you have to use larger slice thickness.

Accordingly, the engineers have designed a kind of hybrid between 2D and 3D ToF: the so-called MOTSA (Multiple Overlapping Thin Slabs Acquisition) to avoid saturation of the inflowing spins and to keep the high resolution in a short time provided by the 3D technique.

Another trick used to avoid early saturation of the inflowing spins is the so-called TONE technique (Tilted Optimized Non-saturating Excitation): essentially the use of a lower flip angle at the entry side and gradually increase to the exit side (as the vessel traverses the slab) so that saturation doesn't occur in the excited slab.

To avoid signal from the veins, a tracking saturation pulse on the cranial (venous) side of the slabs is added.

## How does IV contrast behave on a 3D ToF sequence?

This produces a higher signal in the blood vessels, since the relaxation of Gd-enriched blood is speeded up[1].

The drawback is that you no longer can saturate the venous signal: since the relaxation is faster, the saturation doesn't last.

Since gadolinium is insensitive to the MT-effect and the background remains as sensitive to the MT-effect as prior to gadolinium administration (blood brain barrier), gadolinium administration results in higher flowing blood – enriched with a few drops of gd – to stationary background contrast. This higher contrast (see Figs. 1a-b) can be used to apply a higher matrix. Applying a higher matrix results in smaller voxels, leading to less intra-voxel dephasing, which assists in picking up smaller vessels.

Since we have a faster relaxation, we may use an even shorter TR and higher flip angle to further reduce background signal, without saturation of inflowing spins. In fact, after a little contrast we can use such a short TR that a stimulation monitor will impose a limit!

It is also possible to put the 3D block in an oblique way on the skull base, almost parallel to the circle of Willis, providing a larger coverage of the cerebral blood vessels in the same scan time (same number of slabs).

With this approach a signal is obtained even in the ophthalmic arteries.

## What about the venous enhancement?

Since venous flow is much slower, venous enhancement can be minimized with the use of just a small dose (1 cc), high enough to provide enough relaxation to the fast flowing arterial spins, but not enough for the slower flowing venous spins.

So, the basic principles being remembered, let's look at some examples.

The images were acquired on a MAGNETOM Symphony with Quantum gradients; the standard Head Coil was used. Images pre and post contrast have equal window settings (center and width).

[1] *A rough calculation gives a reduction from the T1 of blood without Gd of 1200 ms towards 500 ms of blood with 1cc of Gd*

1a-b

2a-b

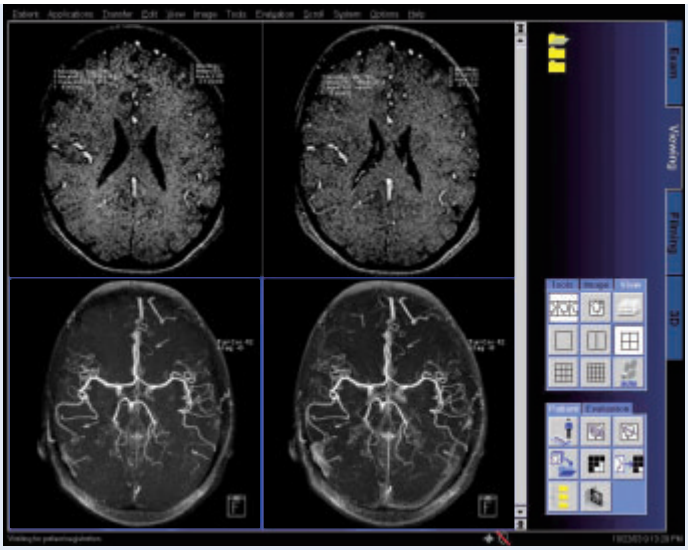


**Figure 1a-b**
*One partition out of the 3D ToF sequence.*
*Left: without Gd;*
*right: with 1 cc of Gd.*

**Figure 1a**
- *ROI # 1(intensity in vessel) = 138*
- *ROI # 2 (intensity in GW) = 83*

**Figure 1b**
- *ROI # 1 (intensity in vessel) = 172*
- *ROI # 2 (intensity in GW) = 82*

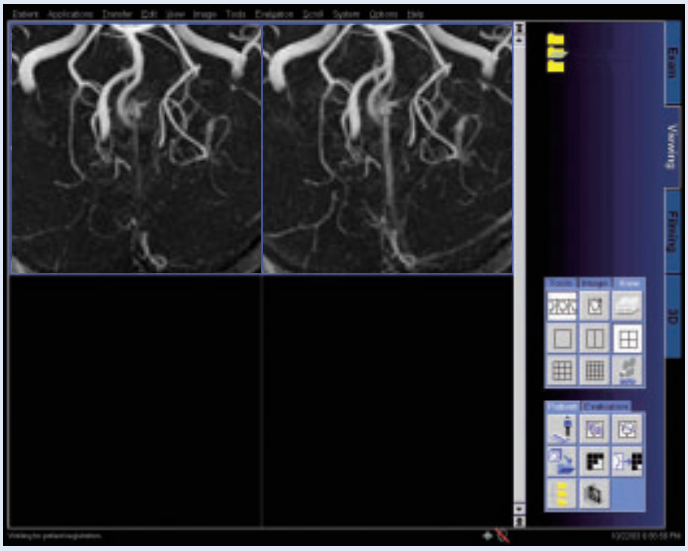


**Figure 2a-b**
*Thick MIP of the 3D ToF.*
*Left: without Gd,*
*right: with 1 cc of Gd.*

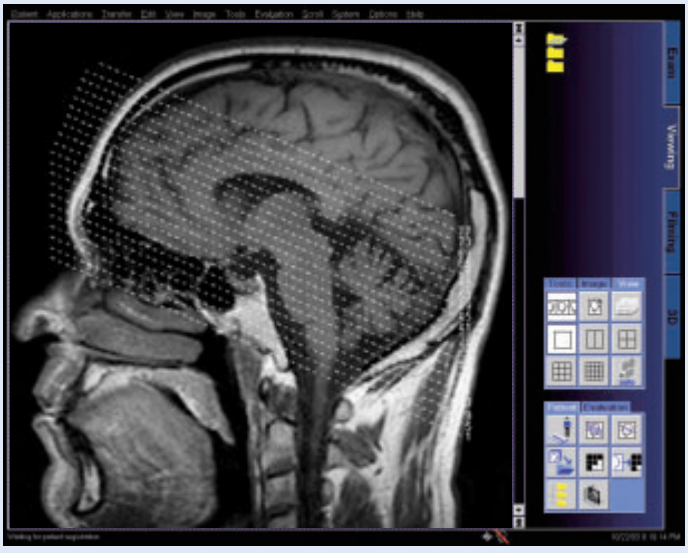
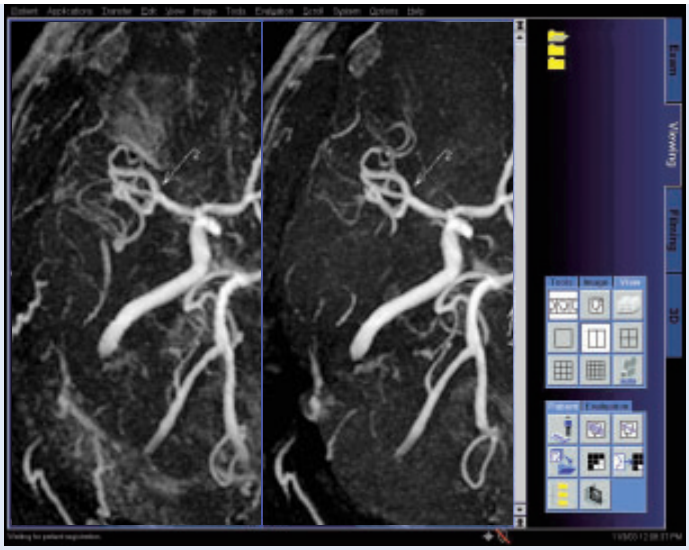


**Figure 3a-b**
*Magnified section out of a thick MIP from a second patient.*
*Left: without Gd;*
*right: with 1 cc Gd.*



**Figure 4**
*Positioning of the partitions of the 3D slabs: inclination of the slabs is increased in regard of the normal "almost pure" transverse positioning.*



*We would like to draw attention to the strength of the "Thin MIP" algorithm to improve the visualization of certain vessels.*

**Figure 5a-b** *1cc enhanced 3D ToF of a patient with left carotid occlusion.*

*Left: standard MIP;*
*right: thin MIP with better visualization of*
*1: lenticulostriatal arteries*
*2: bifurcation artery cerebri media*
*3: PICA*
*4: SCA*

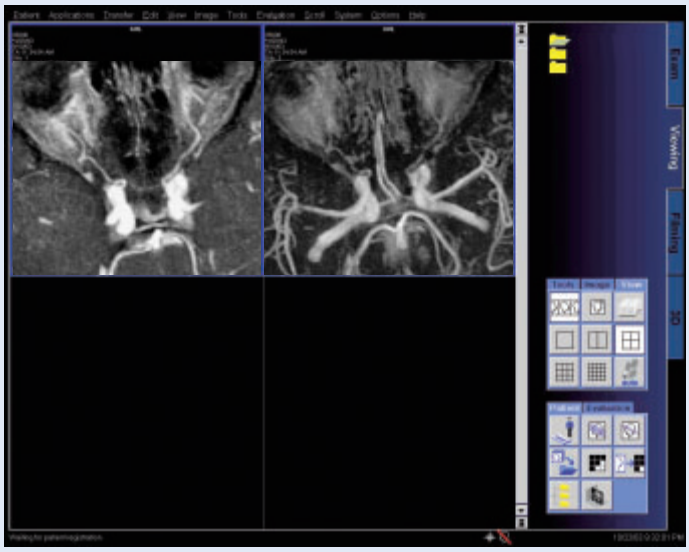


**Figure 6a-b**
*3D ToF enhanced with 1 cc Gd*

*Left: "ThinMIP" nicely depicting the arteria ophtalmica;*
*right: standard MIP.*

The information in this document contains general descriptions of the technical options available, which do not always have to be present in individual cases.

The required features should therefore be specified in each individual case at the time of closing the contract.

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