SIGNA

Pulse of MR

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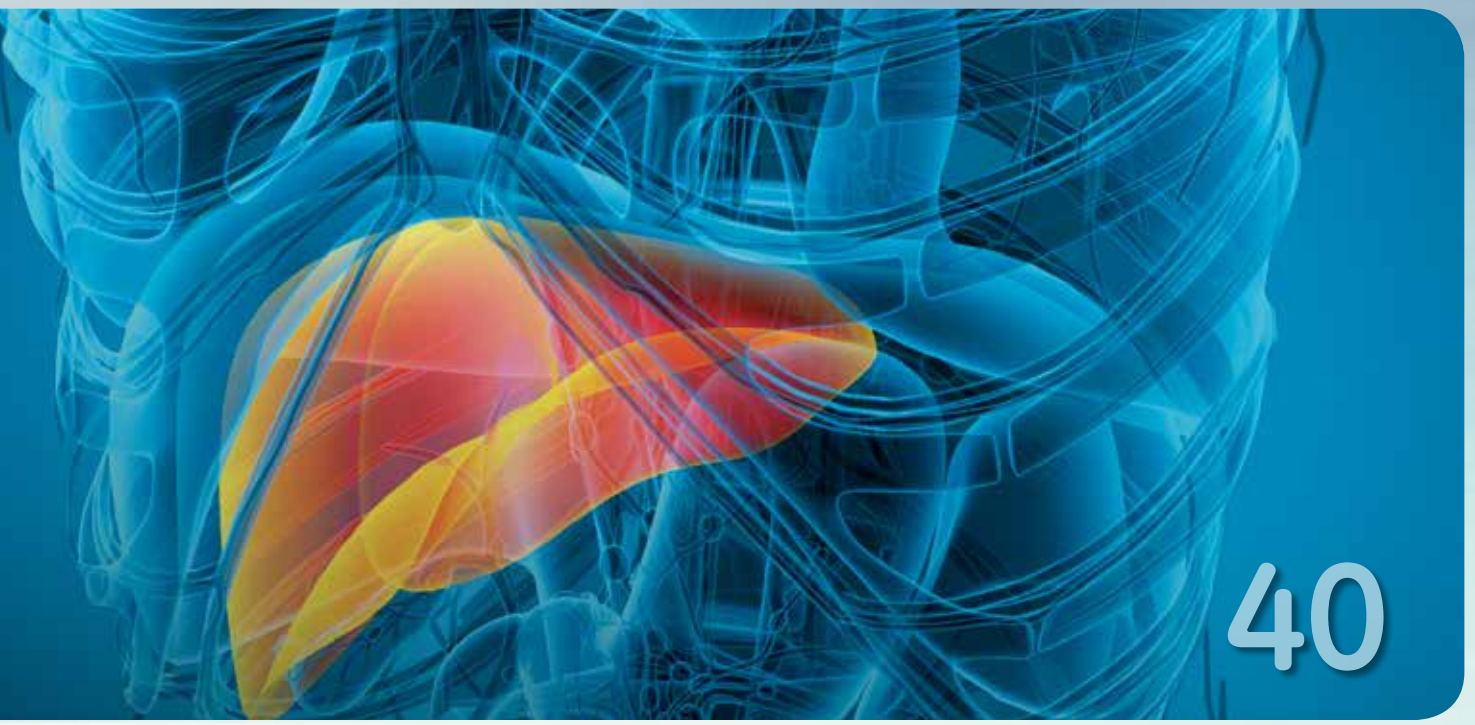
ISMRM Edition

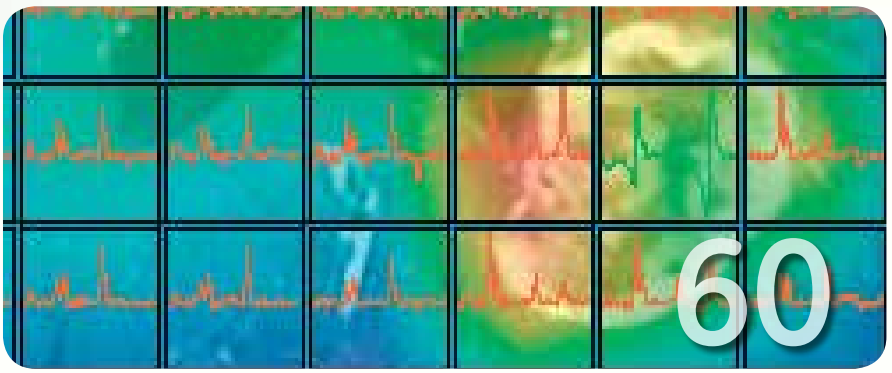
Volume Eighteen

SIGNA™ Returns



Outside the Bore

In Practice



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Welcome

Back in GE's MR business for eight months now, I continue to be amazed by our customers and how they're employing MR in clinical practice and clinical research. The innovations we launched at RSNA and those we are talking about at ISMRM are a result of a focus on you, our customers, and understanding your needs. We are exceptionally cognizant that the healthcare industry is undergoing tremendous change. Be confident that you can count on GE MR more than ever to adapt quickly and develop capabilities that help you deliver exceptional care while addressing your needs for improved productivity.

Our commitment goes back to 1983 when we introduced the SIGNA™ brand and the world's first high-field 1.5T MR system. SIGNA became synonymous with innovation, proven quality, and trust. Just as we revolutionized MR back then, we are changing the course of MR right now with creative, newly designed advancements in technology ready for you to put in practice.

This promise was brought to life at RSNA 2014, where we unveiled four new MR scanners under the SIGNA brand: the SIGNA™ Pioneer‡, a 3.0T wide bore system, leveraging novel productivity enhancements like Magnetic Resonance Image Compilation (MAGiC)‡; SIGNA™ PET/MR (the world's first integrated TOF PET/MR); and SIGNA™ Explorer and SIGNA™ Creator (two versatile 1.5T scanners—with SIGNA Explorer bringing SilentSuite to new markets). Please be sure to read the applicable articles in this SIGNA Pulse of MR—ISMRM Edition. Other amazing advancements covered in this issue include MAVRIC SL, DISCO in prostate and breast imaging, FOCUS DWI at 3.0T, and Orchestra.

Along with this edition, you will find we are once again publishing a SIGNA Pulse of MR Academic Supplement. The focus of this issue is on truly transformative subjects including: TOF PET/MR imaging for attenuation correction and metal artifact reduction; new synthetic MR technology allowing multiple image contrasts in a single scan; RF technology that receives and integrates an MR whole body coil signal simultaneously with a multi-channel surface coil; an approach to generating coils in excess of 64 channels using MEMS technology; approaches to gradient non-linearity correction, and high-slew rate; and parallel imaging and B_0 shimming through a single set of localized surface coils.

For GE, it's exciting to hear from the best and brightest MR minds at ISMRM to understand where the field is moving scientifically and where it's moving clinically. You inspire and challenge us to develop the best tools and highest-performance capabilities that push the boundaries of magnetic resonance imaging. That's our purpose; that's what gets us up in the morning—to help you improve patients' lives.

If you are attending ISMRM, we hope you take time to stop by our booth. You'll experience the four new SIGNA systems and so much more—underscoring our goal of understanding your needs and delivering the most innovative solutions to enable your success. I hope to see you there.

Eric Stahre
President and CEO
Global MR, GE Healthcare

‡SIGNA Pioneer and MAGiC are 510(k) pending at the FDA. Not available for sale in the United States or Canada. Not yet CE marked. Not available for sale in all regions.

MR News

SIGNA Returns

Last fall at RSNA, GE Healthcare announced the return of SIGNA™ with the launch of four new products, the SIGNA™ PET/MR, SIGNA™ Pioneer‡, SIGNA™ Explorer, and SIGNA™ Creator. For 30 years, SIGNA embodied innovation, proven quality, and trust. Just as GE Healthcare revolutionized MR with the SIGNA brand in 1983, it is setting out to revolutionize the future of MR with exciting advancements.

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In-Field Upgrades for GE 1.5T MRI Systems with SIGNA Explorer Lift

GE Healthcare introduced a new in-field upgrade program‡‡ for 1.5T magnetic resonance imaging (MRI) systems in most regions globally. A currently installed GE Healthcare 1.5T LCC magnet may be upgraded to the new SIGNA Explorer Lift so customers can benefit from the modernized patient comfort, workflow efficiency, and diagnostic quality of this system. By upgrading, customers can potentially benefit from cost savings in multiple ways: up to 50% in construction cost, up to 50% savings in equipment cost[1] in comparison to a new 1.5T system, and up to 30% increase in procedures due to increased throughput and referrals[2].

"In a time when healthcare systems are being challenged by reduced reimbursements and longer patient wait times." said Eric Stahre, president and CEO of GE Healthcare MRI, "this upgrade program will enable them to add new clinical capabilities and access the increased efficiency of SIGNA Explorer while leveraging their currnet MR investment. By extending their MR capacity and service lines, clinicians may receive more referrals and therefore potentially generate more revenue. This program reinforces our commitment to the GE Continuum by providing clinicians with solutions to avoid obsolescence and remain up-to-date on the latest clinical offerings."

The upgrade is possible due to the endurance and quality of GE Healthcare's magnet line, which recently celebrated it's 10,000th magnet manufactured and installed from a single magnet line—an industry first.

The upgrade to SIGNA Explorer covers an impressive range of productivity-enhancing applications and new features to enhance patient comfort compared to previous generation systems. For example, SilentScan, GE Healthcare's revolutionary quiet technology, takes patient comfort to a new level. SIGNA Explorer and the upgrade also feature MAVRIC SL, which brings the power of MRI to patients with MRI-conditional metal implants by enabling visualization of soft tissue and bone near the implant. Ⓢ

‡‡This upgrade will start to be made commercially available to the GE Healthcare MRI installed base during the coming months, in the U.S. and other countries where the SIGNA Explorer is available for sale (and has been approved, cleared or registered by the appropriate regulatory authorities). Offer may not be obtainable in all regions. Please contact your local GE representative with any questions about this upgrade program, including if it is available in your region. Exclusions and other terms and conditions may apply.

1. Upfront cost includes equipment, construction required for the equipment install and potential mobile cost during downtime. Actual costs will vary depending on your site's specific circumstances
2. With the SIGNA Explorer Lift, the system may be able to scan 2-3 more patients per day due to new capabilities and productivity.

SIGNA Creator, SIGNA Explorer Receive 510(k) Clearance

Two new 1.5T MR systems built on the proven SIGNA™ platform, the SIGNA™ Creator and SIGNA™ Explorer, have received 510(k) clearance from the FDA. These innovative scanners were designed to help clinicians improve workflow, lower cost of ownership, and impact patient comfort—all with exceptional diagnostic capabilities.

SIGNA Explorer is equipped with GE's revolutionary SilentScan technology, reducing noise levels from the equivalent of a rock concert to just three decibels above ambient for neurological exams. For more information, see page 17.

GE MR Featured in TV News "Love Story"

Jason Polzin, General Manager of Applications and Workflow at GE MR, was recently featured on a TV news segment about a love competition conducted at Stanford University. To visualize the presence of possible changes in bloodflow to various parts of the brain, researchers asked subjects to focus on love for 15 minutes while being scanned in a Discovery™ MR750. Researchers analyzed increases in blood flow to the brain's pleasure centers. The winners were a couple married for more than 50 years.

Read more here: visit tiny.cc/sps153

SIGNA Steals the Show at ECR

The trend-setting, dynamic, and service-oriented European Congress of Radiology (ECR) is well known as one of the most innovative meetings within the scientific community and Europe's biggest medical imaging gathering. At the 2015 event, held in Vienna, Austria, GE MR made a splash with the return of the storied SIGNA brand prominently displayed in the booth. Several new MR systems were showcased, including SIGNA Pioneer‡, SIGNA PET/MR and SIGNA Explorer.

Additionally, at a customer symposium titled "Advances of MR in Oncology," more than 250 attendees learned about GE MR's clinical oncology outcomes—courtesy of Professor Lindsey Turnbull from the Hull Royal Infirmary in the UK. Global CMO, Ioannis Panagiotelis, kicked off the event with a presentation on the current MR landscape and GE's vision for developing new products and solutions for the diagnosis, follow-up, and treatment of cancer patients. He also detailed new products. Also, Dr. Marc Zins from St. Joseph Hospital in Paris presented the clinical added value of the Discovery™ MR750 and Optima™ MR450w with GEM in abdominal oncology. Finally, Dr. Patrick Veit-Haibach from the University Hospital of Zurich—one of three sites chosen to perform GE's clinical trial of the new SIGNA PET/MR—spoke about his experience testing and using the new technology for oncology.

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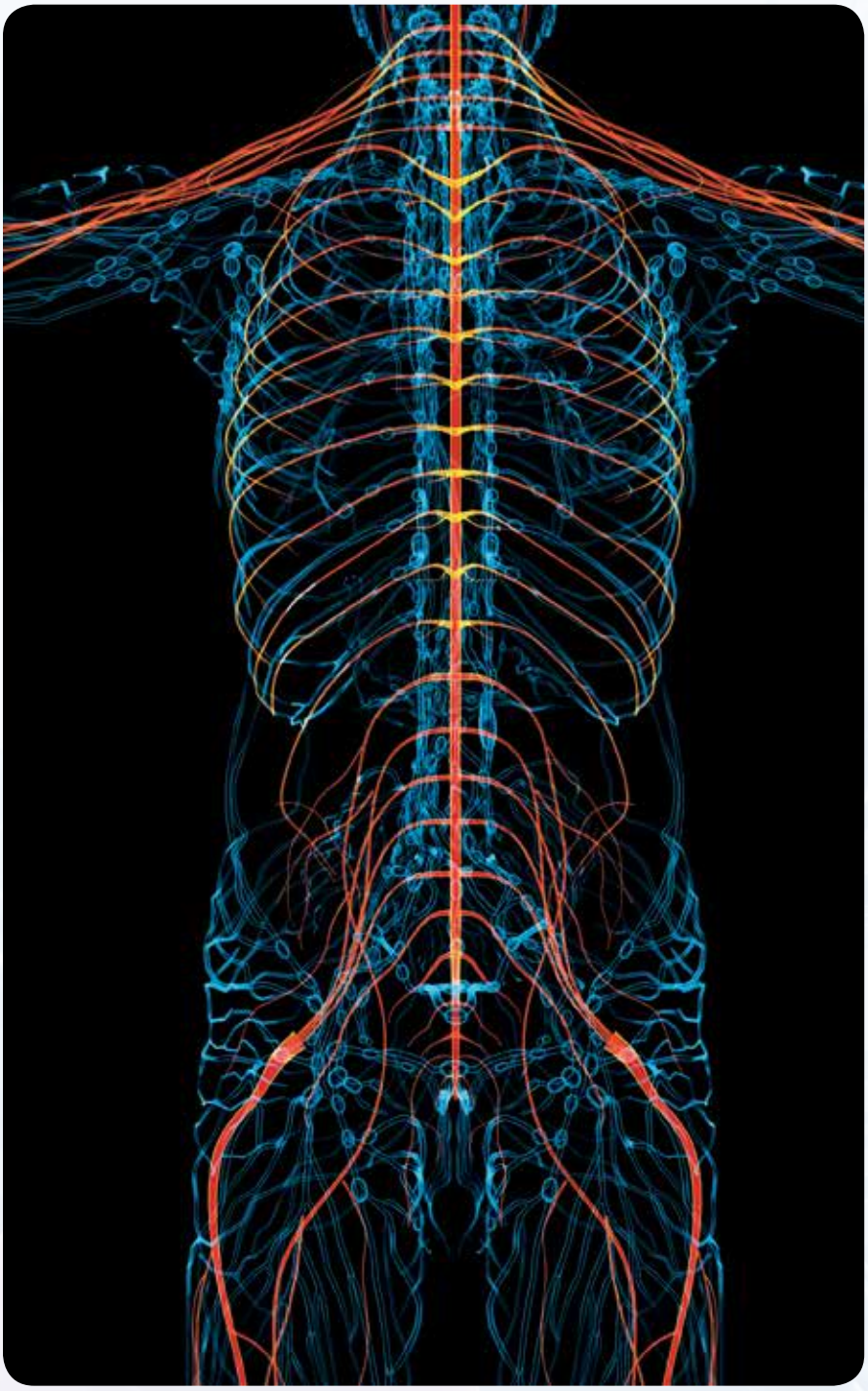
The Role of IDEAL and DTI in Peripheral Nerve MR Imaging

By Darryl B. Sneag, MD, Assistant Attending Radiologist, and Hollis G. Potter, MD, Chairman and The Coleman Chair, MRI Research, Department of Radiology and Imaging, Hospital for Special Surgery



Peripheral nerves pose diagnostic MR imaging challenges. They are sometimes small in caliber and may take an oblique course through intra- and intermuscular fascial planes (e.g. the lumbosacral plexus within the abdomen), making visualization and anatomic mapping difficult with conventional high spatial resolution fast spin echo techniques. Another challenge is distinguishing blood vessels that frequently travel alongside and may demonstrate isointense signal to nerve fascicles.

Figure 1. A patient in their early 40s with one month of pain radiating down the right arm and paresthesias in the fingers presents for 3.0T MR. Oblique Coronal STIR image of the right brachial plexus (A) faintly demonstrates the trunks of the brachial plexus compared with the corresponding IDEAL image (B), in which visualization of the plexus is much more conspicuous. Also note the cardiac pulsation artifact on the STIR sequence that is not apparent on the IDEAL sequence. The brachial plexus was normal in this case.

IDEAL for the Brachial Plexus

The oblique course of the brachial plexus through the neck and its complex, branching anatomy create difficulty in evaluating its fascicular architecture and precisely identifying the site of pathology. Respiratory motion and cardiac pulsation artifacts may obscure portions of the plexus. The inherent curvature of the neck and adjacent lung air make homogeneous fat suppression difficult. In addition to high resolution proton density imaging, which evaluates the contour, caliber, and signal intensity of nerve fascicles, fat suppressed sequences are critical to detect sometimes subtle changes in signal intensity that may be isolated to a particular nerve root or trunk.

Short-tau inversion recovery (STIR) has conventionally been used for fat suppression of the brachial plexus and works relatively well for large field of view imaging. STIR is limited, however, by its low signal-to-noise ratio and sensitivity to flow-related artifacts. IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation), a "three-point" (three-echo acquisition) Dixon fat suppression sequence, provides more homogeneous fat suppression and reduced pulsation artifact compared with STIR (Figure 1). Dixon chemical shift imaging involves combining "in-phase" and "out-of-phase" sets of images, acquired with slightly different echo times based on the different resonance frequencies of fat and water, to produce "fat-only" and "water-only" images. The "water-only" images are fat suppressed and the "fat-only" images can be used for fat quantification. Different weightings can be applied to the IDEAL sequence, available on 1.5T and 3.0T scanners, but to enhance nerve signal and highlight pathology, T2-weighting is generally employed.

Clinical indications for brachial plexus MR are numerous and include post-traumatic injuries, typically in young patients involved in motor vehicle accidents, or in the setting of recent shoulder dislocation, thoracic outlet syndrome, tumor, and a myriad of inflammatory conditions including radiation plexitis and idiopathic and hypertrophic polyneuropathies, such as Parsonage-Turner syndrome and chronic inflammatory demyelinating polyneuropathy (CIDP), respectively.

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is Chairman, Department of Radiology and Imaging and The Coleman Chair, MRI Research, Hospital for Special Surgery in New York, NY.

Case 1

A patient in their early 70s with a long history of slowly progressive right arm and hand weakness, upper arm swelling, as well as pain and numbness of her first two fingers was referred for MRI of the brachial plexus. The patient was previously diagnosed with polymyalgia rheumatica and treated with steroids, with no relief of symptoms, as well as with carpal tunnel syndrome.

Using the IDEAL technique, MRI revealed hypertrophic fascicular architecture (Figure 2), thought to represent an inflammatory demyelinating polyneuropathy, which was confirmed clinically.

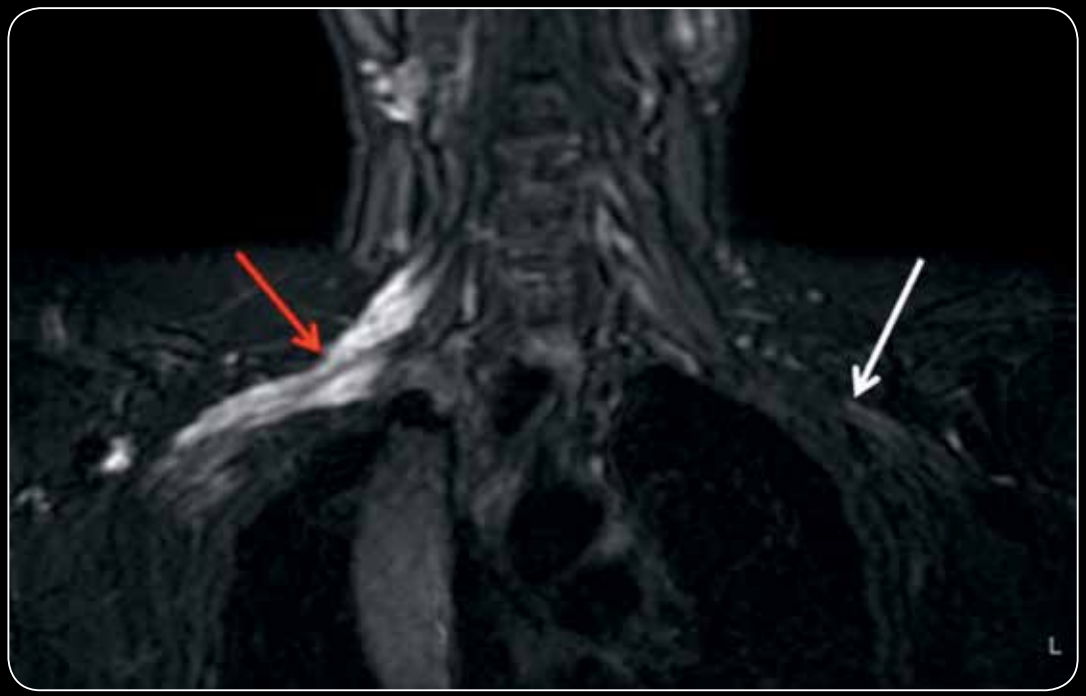

Figure 2. 3.0T Coronal T2w IDEAL image demonstrates diffuse, marked thickening and signal hyperintensity of the right brachial plexus fascicles (red arrow). Compare to the normal left-sided plexus (white arrow).

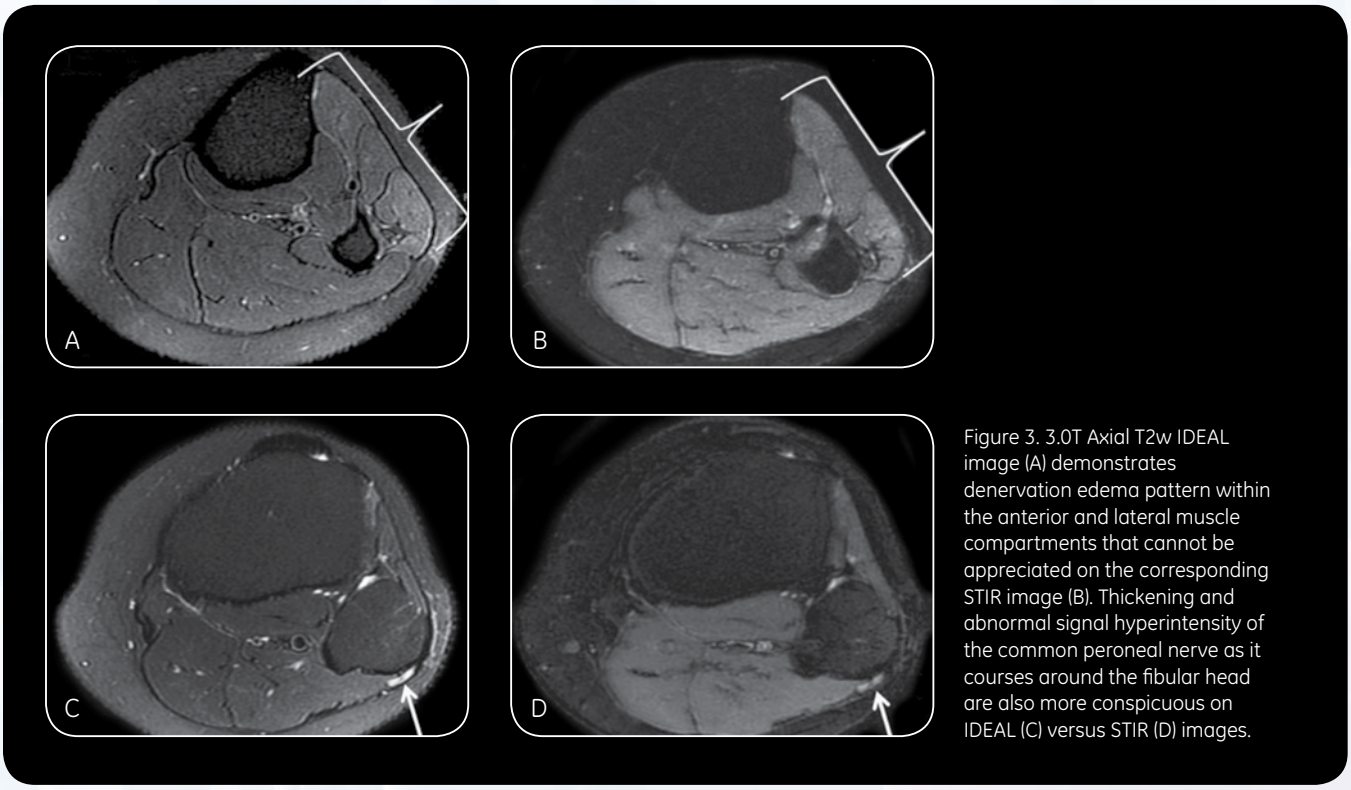

Figure 3. 3.0T Axial T2w IDEAL image (A) demonstrates denervation edema pattern within the anterior and lateral muscle compartments that cannot be appreciated on the corresponding STIR image (B). Thickening and abnormal signal hyperintensity of the common peroneal nerve as it courses around the fibular head are also more conspicuous on IDEAL (C) versus STIR (D) images.

IDEAL: Beyond the Plexus

The IDEAL fat suppression technique can also be readily used as an alternative to STIR in the extremities. As shown in Figure 3, a critical component of peripheral nerve imaging is evaluating the target organ: the muscle that each nerve innervates. Unless denervation is chronic and complete, in which the muscle belly will appear completely fatty atrophied, denervation will manifest as an edema pattern of the muscle. IDEAL is particularly suited to 3.0T systems, on which the majority of our peripheral nerve imaging exams are performed, as potential flow-related and motion artifacts are magnified as compared to 1.5T.

Case 2

A 27 year-old patient with a recent onset of myasthenia gravis presented to her neurologist with acute numbness along the lateral aspect of her right lower leg and dorsum of foot following several bouts of intense calf cramping. The clinical diagnosis was a common peroneal neuropathy, confirmed with electrodiagnostic testing. Subsequent MR imaging (Figure 3) to evaluate the cause of the neuropathy demonstrated marked signal hyperintensity of the common peroneal nerve at the level of the fibular head, without a compressive mass. Axial IDEAL imaging demonstrated mild denervation edema pattern of the anterior and lateral compartment musculature that could not be appreciated on the corresponding axial STIR sequence. Electromyography was not able to detect muscle denervation, which typically takes one to four weeks to manifest.[1] A diagnosis of idiopathic entrapment of the common peroneal nerve was made and symptoms spontaneously resolved a week later.

IDEAL is a commercially available pulse sequence that has a wide variety of applications in musculoskeletal imaging. More recently, IDEAL has been recognized as an important tool for peripheral nerve MR imaging as it offers homogeneous, robust fat suppression that is critical for reliably evaluating nerve signal and fascicular architecture, and detecting

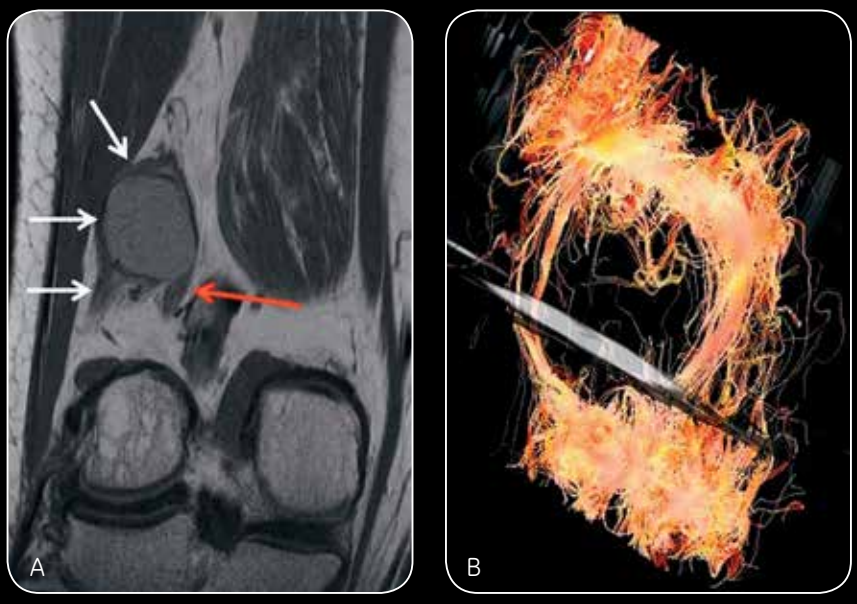

Figure 4. Coronal proton density (A) and diffusion tractography (B) images demonstrate a peripheral nerve sheath tumor within the posterior distal thigh arising from the common peroneal nerve (white arrows) and displacing the tibial nerve (red arrow) medially.

muscle denervation. One limitation of the sequence is its sensitivity to paramagnetic susceptibility from metallic hardware and in these cases MAVRIC SL inversion recovery techniques should be used. IDEAL is available for both 3.0T and 1.5T systems.

Diffusion Tensor Imaging (DTI)

DTI is a quantitative and commercially available, functional imaging technique that aims to characterize the three-dimensional motion of water molecules in biological tissues. DTI has historically been used to evaluate white matter tracts in the brain, predominantly for pre-operative planning but more recently has been applied to the peripheral nervous system. Normal peripheral nerves are inherently anisotropic as their well-organized architecture renders water molecules more likely to traverse along the longitudinal nerve axis than in any other direction. Using the DTI sequence, fractional anisotropy (FA) values can be generated to help the physician monitor "nerve health" or axonal integrity. In the setting of nerve entrapment such as carpal tunnel syndrome[2] or crush injury resulting in Wallerian degeneration[3], FA values will generally decrease.

Another DTI technique to evaluate the structural integrity of peripheral nerves is through tractography. Using the source DTI data, three-dimensional tractography images can be generated to demonstrate nerve integrity following penetrating or crush injury as well as to visualize regeneration following repair, grafting or transfer procedures.[4] Tractography is also valuable in defining the trajectory of a nerve in relation to a soft tissue tumor (Figure 4). S

References

1. Tjoumakaris FP et al. Neuralgic amyotrophy (Parsonage-Turner syndrome). J Am Acad Orthop Surg. 2012; 20:443-9.
2. Guggenberger R, Markovic D, Eppenberger P, et al. Assessment of median nerve with MR neurography by using diffusion-tensor imaging: normative and pathologic diffusion values. Radiology 2012; 265:(1):194-203.
3. Yamasaki T, Fujiwara H, Oda R, et al. In vivo evaluation of rabbit sciatic nerve regeneration with diffusion tensor imaging (DTI): correlations with histology and behavior. Magn Reson Imaging 2015;33:95-101.
4. Simon NG, Narvid J, Caget T, et al. Visualizing axon regeneration after peripheral nerve injury with magnetic resonance tractography. Neurology 2014;83:1382-4.

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Hospital for Special Surgery, *Founded in 1863, is the nation's oldest orthopedic hospital. More than 25,000 surgical procedures are performed annually. HSS performs more hip surgeries and more knee replacements than any other hospital in the nation. The hospital is nationally ranked #1 in orthopedics, #3 in rheumatology, and #7 in geriatrics by U.S. News & World Report (2014-2015).*

SIGNA Explorer Brings Advanced Apps to Mikuni Hospital

In November, 2014, the brand name SIGNA™ returned with the introduction of two new 1.5T MR systems—the SIGNA™ Explorer and SIGNA™ Creator. Both systems are designed for improved patient comfort and productivity and aim to address clinicians' pain points. The systems help clinicians save time with an automated workflow—including volumetric imaging acquisitions like Cube, automated brain exams via READY Brain, and simplified whole body diffusion imaging. OpTix Optical RF technology can also help boost image quality with premium analog to digital signal conversion that can provide a gain in SNR of up to 27% over conventional analog signal receivers.

Both SIGNA Explorer and SIGNA Creator—designed to lower total cost of ownership—use 34% less power than previous generation MR systems and require a smaller footprint for installation.

SIGNA Explorer offers clinicians an added patient-comfort touch: SilentScan neuro exam. SilentScan, GE Healthcare's revolutionary technology, takes patient comfort to a new level. Conventional MRI scanners can generate noise in excess of 110 decibels (dBA), the equivalent of a rock concert or jackhammer levels. The Silenz pulse sequence dramatically reduces the scan to just three dBA above ambient noise for neuro exams, a major differentiator for patient comfort. Another useful sequence available on the SIGNA Explorer is FOCUS, which

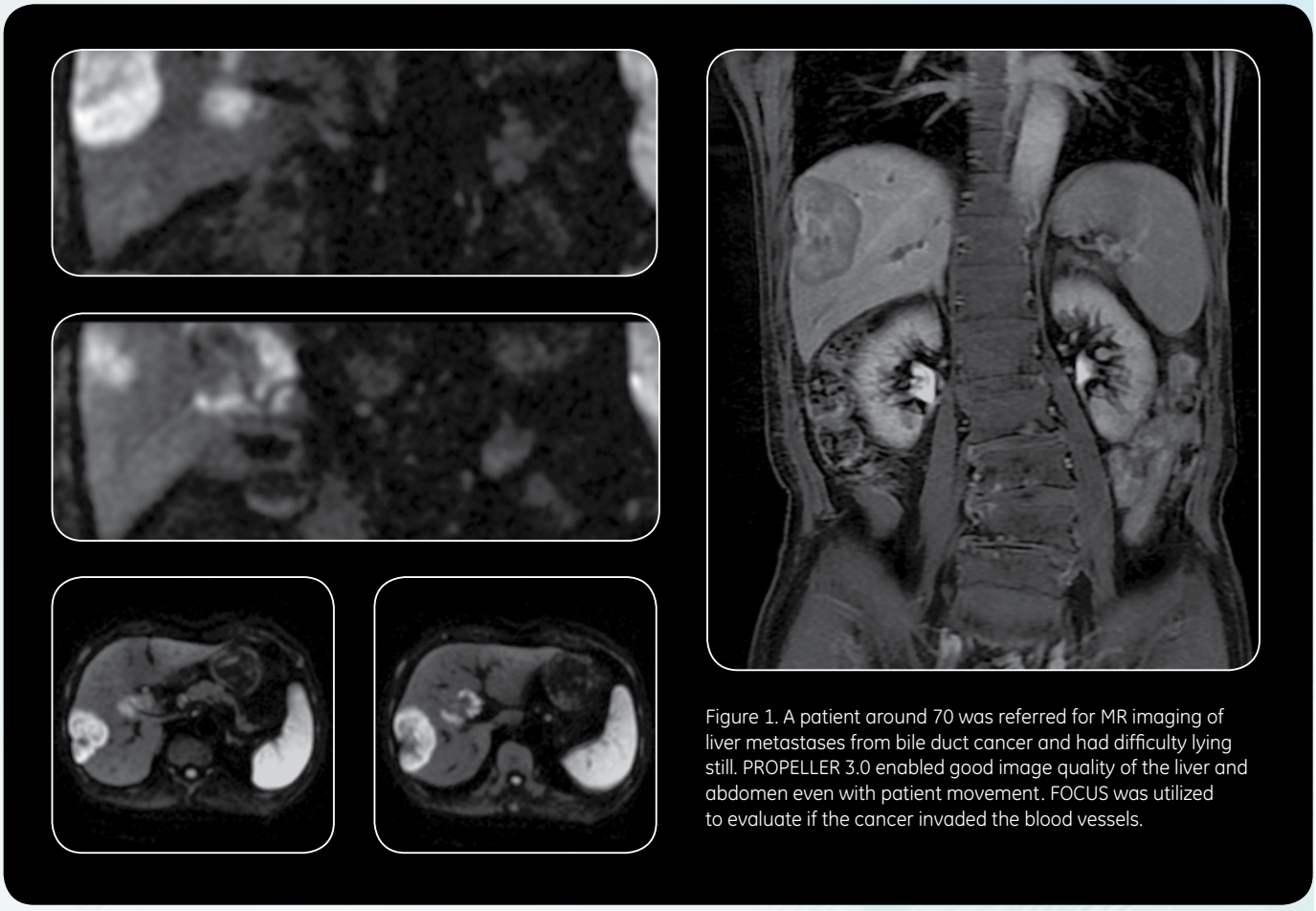

Figure 1. A patient around 70 was referred for MR imaging of liver metastases from bile duct cancer and had difficulty lying still. PROPELLER 3.0 enabled good image quality of the liver and abdomen even with patient movement. FOCUS was utilized to evaluate if the cancer invaded the blood vessels.

delivers a highly efficient method for increasing the resolution in Single Shot DW EPI sequences. Utilizing a multi-dimensional selective excitation, FOCUS supports zoomed, small field of view imaging of specific organs with higher diagnostic quality, lower artifacts, and faster exam times compared to conventional diffusion imaging.

Sakai Municipal Mikuni Hospital in Fukui, Japan is one of the first worldwide users of the SIGNA Explorer 1.5T MR System. As a GE SIGNA™ Horizon LX user for 15 years, the facility turned to GE Healthcare to replace the aging system. The small footprint SIGNA Explorer requires less room, so it was the perfect solution for the space-constrained imaging department.

"My first impression is that the system is simply magnificent," says Toru Shibue, RT, a radiologic technologist at Mikuni Hospital. "Our image quality has improved a lot with the higher SNR and we can see the impact of the OpTix technology," he says. In fact, the hospital's radiologists have told Mr. Shibue that the high quality images have helped increase their confidence in the diagnosis.

"Without increasing examination time, we can now acquire a lot more valuable and important clinical information for the radiologists, and that helps them with their diagnosis. They've specifically commented on how much better the MRA images are getting," he adds.

Not only are the scan times shorter, which Mr. Shibue expected, but pre-scan time and reconstruction time are also significantly shorter. "On the previous system, we spent one minute for pre-scan tuning, but now it is much shorter, just a few seconds, and with more robust fat suppression on the SIGNA Explorer."

In addition to the efficient workflow, the new sequences and imaging capabilities are making a big impact on the quality of the MR exams. Mr. Shibue recalls a case where a patient with a cerebral aneurysm was scanned on the prior system, then received a follow up on the new SIGNA Explorer (Figure 2).

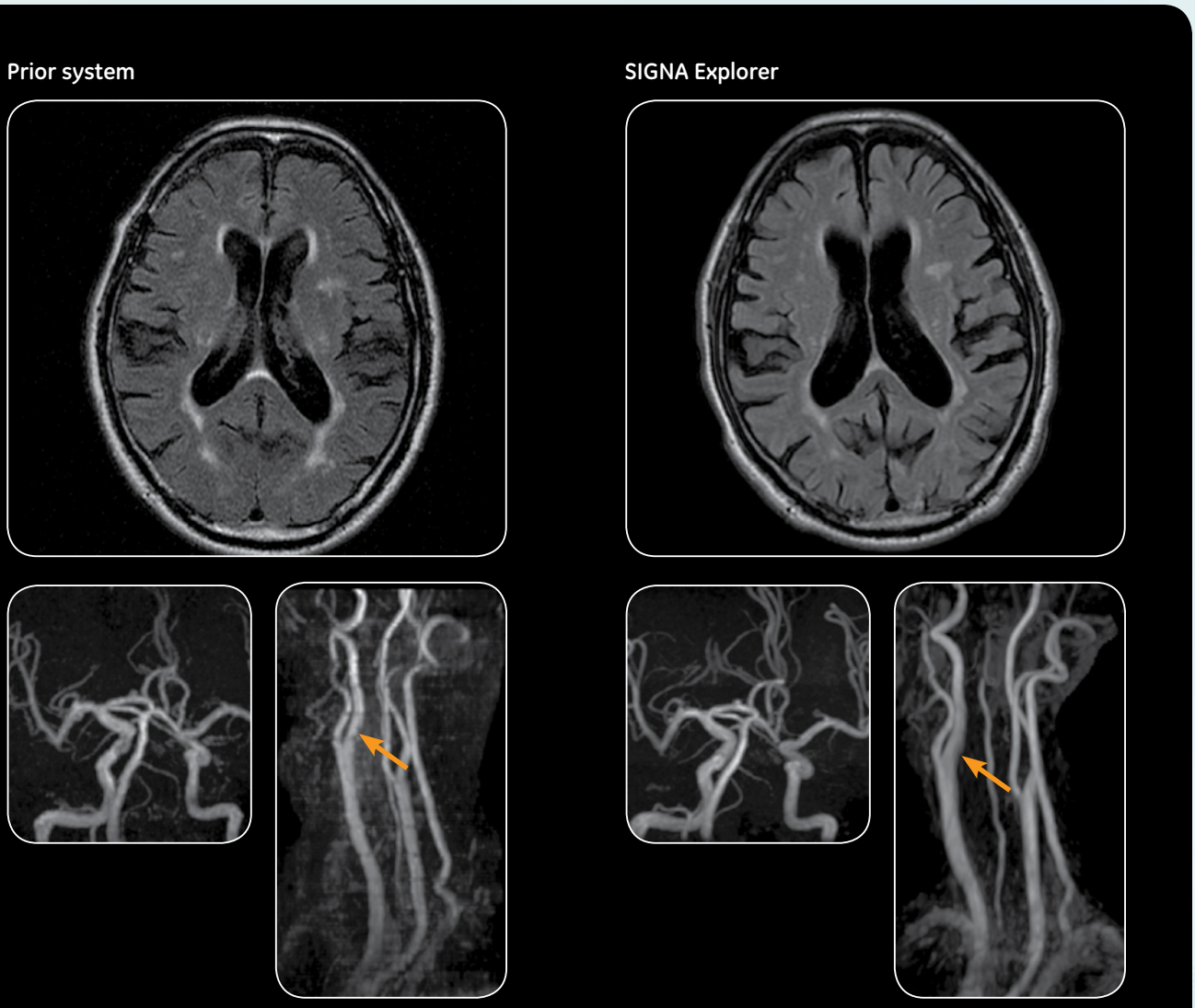

Figure 2. Comparison of a patient who was initially scanned on the prior system and then again on the SIGNA Explorer for follow up of a cerebral aneurysm. On the first exam (left), a stenosis at the origin of the internal carotid artery was suspected, however MRA image quality was not sufficient for a definitive diagnosis. On the SIGNA Explorer exam (right), it was possible to rule out stenosis. Other contrast images on the SIGNA Explorer were also improved due to the increase in SNR and reduction of CSF artifact.

Toru Shibue, RT,
is Chief Radiologic Technologist at Sakai Municipal Mikuni Hospital in Fukui, Japan.

"On the first exam, our radiologists suspected there was stenosis at the origin of the internal carotid artery. However, the follow-up MR exam provided the information to assess that this was not the case, due to the improved image quality of the MRA image. SNR increased in the other contrast images and, providing a clearer picture of the patient's condition," Mr. Shibue explains.

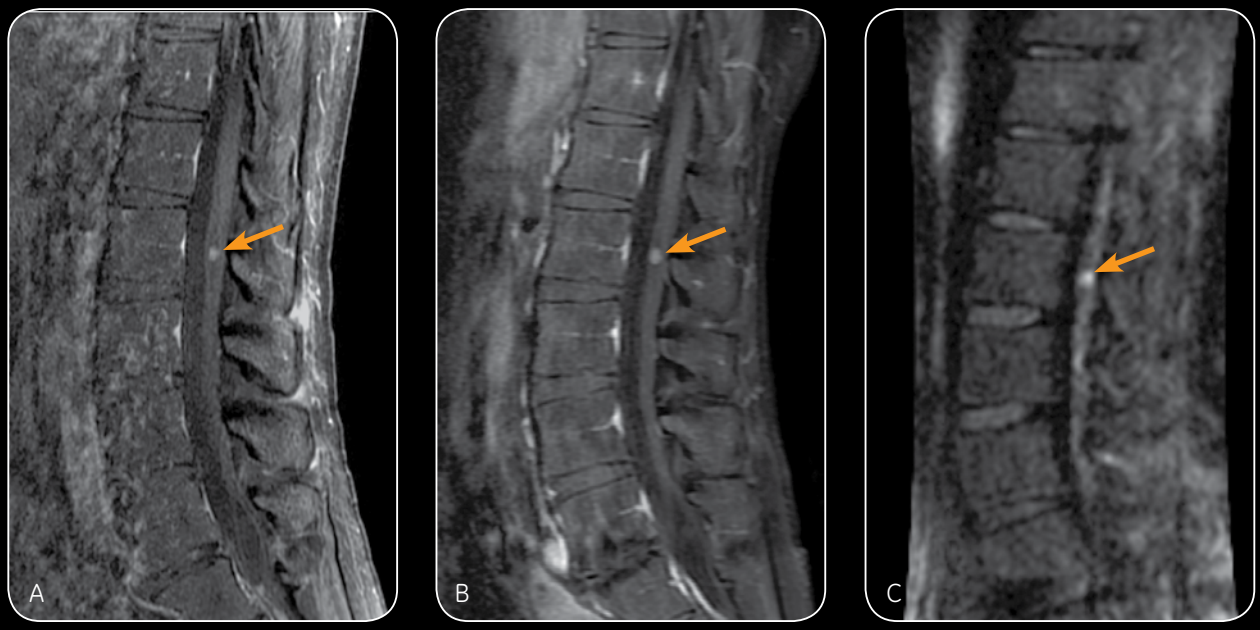

Figure 3. Patient's initial exam was performed on prior system (A); follow up exam for mass around cauda equine was performed on SIGNA Explorer (B). The FOCUS sequence (C) provided high resolution DWI and was easily added to the scan, further helping the clinician diagnose the lesions.

Advanced applications are also providing several clinical advantages in difficult patient cases. Specifically, FOCUS is highly regarded by the radiologists for providing additional information for diagnosis due to its high resolution and less distorted DWI images. "We often add the FOCUS sequence in cases of suspicious lesions. It doesn't have any coil limitation, so we can add FOCUS on any anatomy scan," Mr. Shibue adds.

Body Navigator is another useful tool, particularly on patients who cannot hold their breath. Mr. Shibue finds the biggest benefit when performing hepatocyte phase imaging using Primovist EOB. He also frequently uses Navigator 3D MRCP exams. "It's not only helpful for our patients, but it helps reduce re-scans," he says.

With a large elderly population, patient movement is often an issue. Mr. Shibue utilizes PROPELLER 3.0 in abdominal scans, particularly liver imaging. "PROPELLER 3.0 is amazing as well. I was surprised the first time we used it to see coronal images of the abdominal area which was taken by PROPELLER 3.0," he says, adding that PROPELLER 3.0 is now consistently used for imaging of the abdominal area.

SIGNA Explorer's detachable table is also helpful with the hospital's older patients, as it can be lowered for the patient to more easily get on and off the table. The HNS coil also facilitates imaging of the most frequent MR

> "We often add the FOCUS sequence in cases of suspicious lesions. It doesn't have any coil limitation, so we can add FOCUS on any anatomy scan."
>
> *Mr. Toru Shibue*

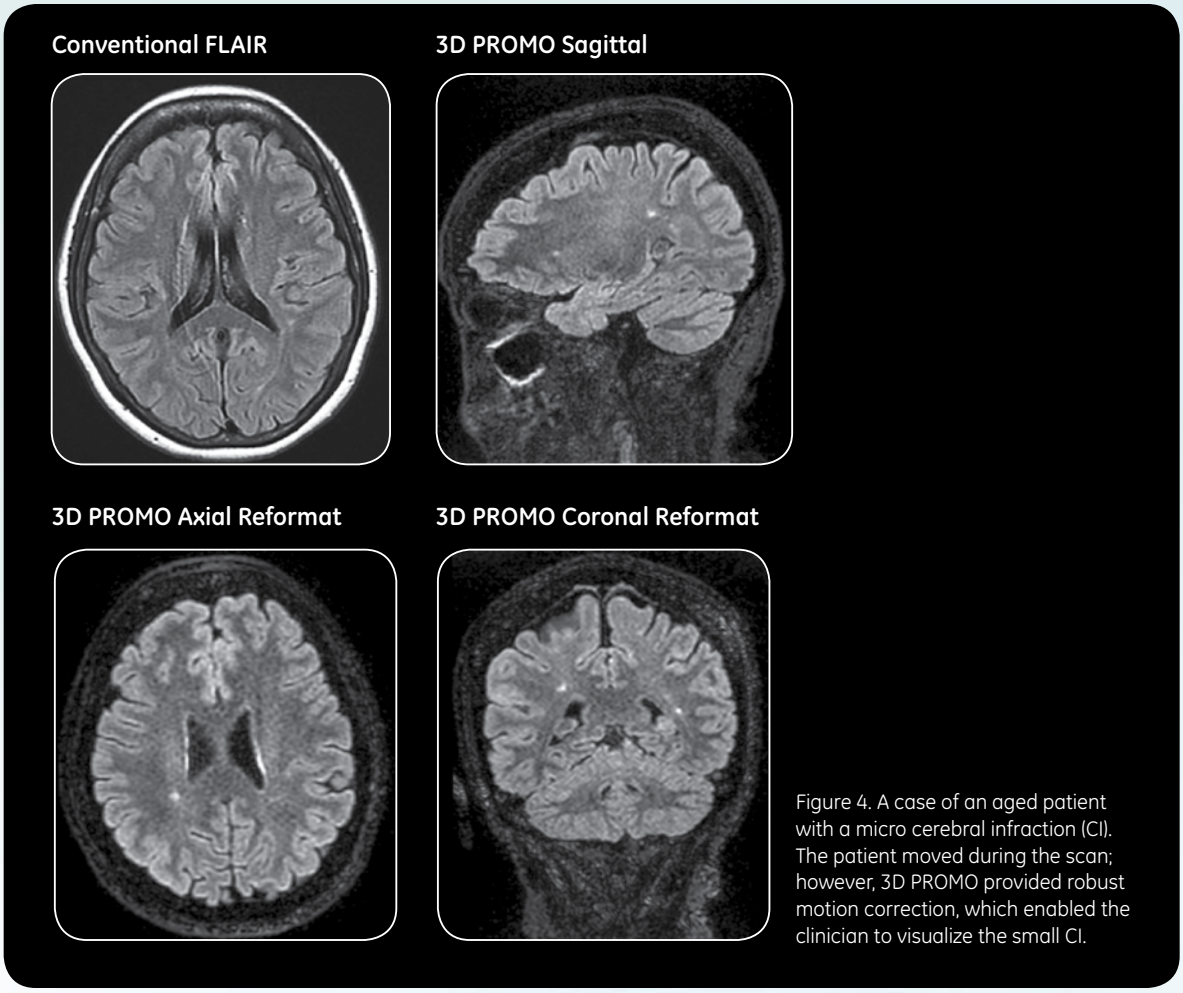

Figure 4. A case of an aged patient with a micro cerebral infraction (CI). The patient moved during the scan; however, 3D PROMO provided robust motion correction, which enabled the clinician to visualize the small CI.

studies performed at Mikuni Hospital—head, neck, and spine. Mr. Shibue explains, "Coil handling is now easier, because with the HNS coil we can keep the spine coil for head and neck studies and keep the head and neck coil for spine—so there is less changing of the coils, which has reduced our patient positioning time."

Mikuni Hospital has only had the new scanner operational since March, 2015, so not all the new sequences have been utilized. In particular, Mr. Shibue is excited to use 3D PROMO and SilentScan.

"Shortly after we started using SIGNA Explorer, we performed an MR scan of a patient with a micro cerebral infarction," says Mr. Shibue. "Since the patient moved during the scan, we tried 3D PROMO. It provided robust motion correction and enabled us to acquire high resolution 3D images. The small cerebral infarction could also be well visualized."

"Sometimes we have a patient who can't stop moving, so I think 3D PROMO would be very useful," he says. "We have already started using PROPELLER 3.0 but 3D PROMO is useful for correcting 3D movements, and we believe that will be very beneficial."

While volunteer scans have been conducted using SilentScan, Mr. Shibue sees this as an excellent sequence when imaging young children, who are often frightened by loud scanning sounds. He adds, "All of our volunteers were surprised at the reduction in noise. When we started using the system, I never imagined being able to provide such quiet exams!"

Toru Shibue, RT, *is Chief Radiologic Technologist at Sakai Municipal Mikuni Hospital in Fukui, Japan. For 28 years he has been a radiologic technologist, with 15 years of experience in MR imaging. Mr. Shibue is also Chairperson of GE Healthcare's MR users meeting in Japan.*

Sakai Municipal Mikuni Hospital *is a municipal general hospital with 105 beds that has been established as a core hospital of the region. The hospital provides a variety medical services in the departments of surgery, orthopedics, neurosurgery, dermatology, urology, internal medicine, ENT, pediatrics, obstetrics and gynecology, ophthalmology, Radiology, and more.*

A New Chapter Emerges in PET/MR Imaging

In November, 2014, GE Healthcare announced that the first integrated, simultaneous, time-of-flight (TOF) capable, whole body SIGNA™ PET/MR received US FDA 510(k) clearance. The SIGNA PET/MR represents a new chapter in helping clinicians achieve improved scan efficiency that may lead to more effective treatment paths for clinicians to offer their patients, particularly for oncology, neurology, and cardiology patients.

MR is excellent for imaging soft tissue as well as functional and morphological details. PET enables clinicians to visualize cellular activity and metabolism. When these two powerful tools are combined, clinicians may be able to see early cellular changes that can be accurately mapped onto MR images. What does this mean? With this knowledge, clinicians may be able to shorten the time between diagnosis and treatment, in addition to offering the convenience of simultaneous PET and MR scans for patients.

The SIGNA PET/MR features GE's new, exclusive MR-compatible silicon photomultiplier detector (SiPM) technology. This new digital detector is characterized by its enhanced sensitivity; it is up to three times more sensitive than conventional PET technology. It also features fast coincidence timing resolution enabling TOF reconstruction. With TOF reconstruction, the arrival times of each pair of coincident events are more precisely detected, and the time difference between them is used to localize the PET signal accurately. TOF leads to improved PET image quality with higher structural detail from the improved signal-to-noise ratio. In addition, sites with the Discovery™ MR750w 3.0T have the option to upgrade to the SIGNA PET/MR.

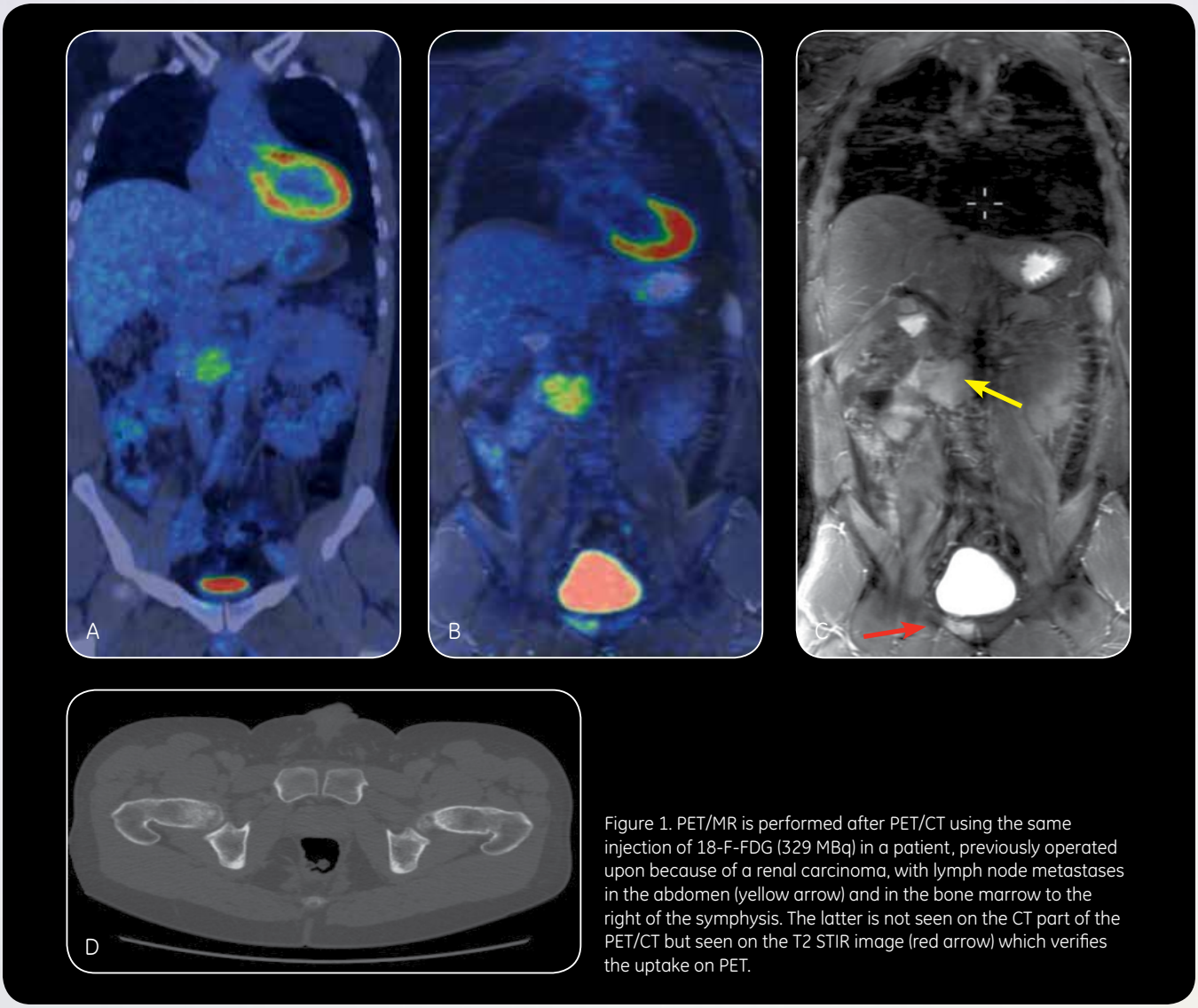

Figure 1. PET/MR is performed after PET/CT using the same injection of 18-F-FDG (329 MBq) in a patient, previously operated upon because of a renal carcinoma, with lymph node metastases in the abdomen (yellow arrow) and in the bone marrow to the right of the symphysis. The latter is not seen on the CT part of the PET/CT but seen on the T2 STIR image (red arrow) which verifies the uptake on PET.

Uppsala University Hospital

Often referred to colloquially as "Akademiska," Uppsala University Hospital is an 1,100-bed teaching hospital and tertiary referral hospital for the Uppsala/Örebro healthcare region in Sweden. With a rich history as Sweden's oldest university hospital, Uppsala continually seeks new and innovative technologies that can propel its clinical research and enhance the quality of patient care.

As one of the initial SIGNA PET/MR pilot sites and first users of the system, Uppsala is utilizing this system in several clinical studies. According to Håkan Ahlström, MD, Chairman, Department of Radiology, Oncology, Radiation Sciences and Professor of Radiology at Uppsala, one of the primary tasks is to determine how the system will be used in clinical practice.

"Certainly, we have already seen benefits in imaging oncology patients and of course that is well described in the literature," Professor Ahlström explains. "We believe there is the ability to obtain more visual information than other techniques, especially for investigating the whole body."

The ability of PET/MR to perform whole body imaging could enable Professor Ahlström to identify an extension of the disease or distant metastases. This approach he calls the "one-stop shop investigation," providing valuable clinical information critical to deciding the best treatment for each individual patient. The lack of ionizing radiation from CT is, of course, an added benefit especially when dealing with younger patients, he adds.

"Previously with MR, we focused on the primary tumor but didn't investigate the whole patient," Professor Ahlström says. Continued advancements in MR

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technology now enable this type of study to be performed in a clinically reasonable time, he adds. "We can image the whole body, from the feet to the head, to capture the whole picture of systemic disease."

"In tumors that metastasize to the liver, MR is excellent," Professor Ahlström says. "Also, for skeletal, it is very sensitive for the visualization of bone marrow metastases; of course, in the head and neck regions, including the brain, MR is more sensitive than CT."

In several evaluations of the sensitivity of the SIGNA PET/MR in these anatomical areas, he notes that, "We can find many lesions with PET/MR that can change the patient treatment plan." In one patient with known metastatic disease in the lymph nodes, PET/MR detected additional liver and bone metastases. Finding metastases in the liver and bone will most often change the patient treatment regimen, he adds.

In a patient with colonic cancer, the whole body imaging capability of PET/MR helped Professor Ahlström discover another tumor in the colon that was previously not seen, as well as metastases in the lung. He says he can also more clearly see the shape and size of intestinal tumors, in particular growths that are outside the wall of the intestine in the mesentery fat.

Imaging neuroendocrine tumors is another area where PET/MR shines. Using Ga-68 DOTA-TOC‡ PET simultaneously with MR, Professor Ahlström is able to see very small metastases, including ones found in the liver. He does believe that the longer PET detector (25cm axially) in the SIGNA PET/MR contributes to the higher sensitivity.

"I can see much higher resolution and more sensitivity for small lesions with this PET/MR," he says. This higher sensitivity is due to the systems pioneering TOF technology with digital PET detector modules based on Silicon Photomultipliers (SiPM) with excellent timing resolution of less than 400ps. Scintillator crystal dimensions of 4.0mm x 5.3mm x 25mm complemented by a 25cm axial FOV delivers exceptional NEMA PET sensitivity of 21 cps/KBq, three times higher than previous generations of PET technology.

Yet, it's not just in oncology where Professor Ahlström says he sees great potential. Bringing together two functional imaging systems—PET and MR—could be an excellent imaging tool for evaluating cardiac function and perfusion.

"We have performed several cases with Oxygen 15 to examine the blood flow in the myocardium," he explains. While CT angiography is excellent for depicting morphological changes, there are cases where the morphology is normal yet the patient is suffering from chest pain, he adds. MR can help detect these cases of compromised perfusion.

Professor Ahlström also sees potential for using PET/MR for imaging patients with neurodegenerative diseases. "There is also huge potential to utilize PET/MR to visualize prostate cancer with 11C-choline or 11C-acetate for primary tumor and lymph node metastases and 18F for skeletal tumors in high risk tumors. The synergy of PET with these tracers and MR is obvious," he adds.

One area where Professor Ahlström would like to see technical improvements is in the ability of treatment delivery systems—both linear accelerators and proton therapy—to be more compatible with PET/MR systems. The need, he says, is in dose painting, wherein certain areas of the tumor may need a higher radiation dose than others, particularly if the tumor is hypoxic.

For other sites considering adding PET/MR to diagnostic imaging offerings, Professor Ahlström says one of the most important considerations is to have the staff with the right skill sets. "This is a complicated technique that requires staff with different knowledge of PET and MR technologies," he says. At Uppsala, by having PET/MR in the same building as the facility's 3.0T MR, there is an optimum environment for collaboration.

‡Uppsala University Hospital is currently studying the potential use of Ga-68 DOTA-TOC tracer in the evaluation of certain neuroendocrine disorders. Ga-68 DOTA-TOC is not FDA approved and is being utilized in this study under an IND.

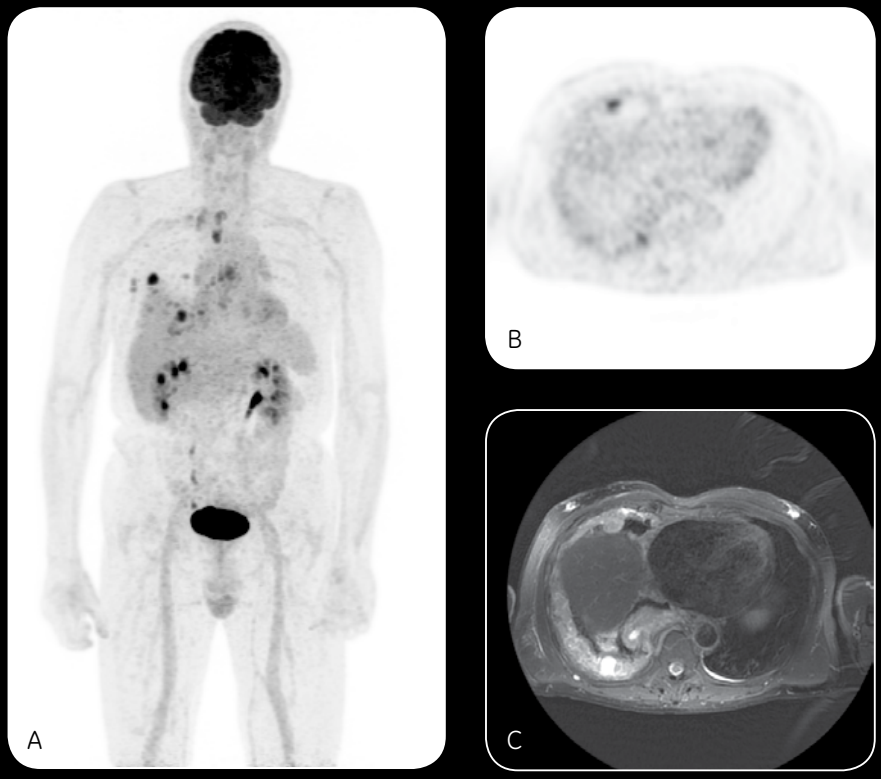

Figure 2. Patient with a known malignant pleural mesothelioma. PET/MR was acquired to evaluate the extent of the disease and specifically to evaluate the relationship of the tumor to the pleura, the diaphragm, and the pericardium after inductive chemotherapy. Furthermore, PET/MR is able to distinguish between the metabolically active area of the tumor in contrast to only morphologically contrast-enhancing areas of the tumor.

University Hospital Zurich

The University Hospital Zurich (USZ) has a full complement of imaging tools to deliver cutting-edge medicine, including the new SIGNA PET/MR and GE's Trimodality PET/CT+MR solution, consisting of a PET/CT and a Discovery™ MR750w 3.0T system. Located in the heart of Zurich, USZ was the first hospital in the city with a recorded history dating back to the year 1204.

According to Patrick Veit-Haibach, MD, Section Head PET/MR, USZ is conducting some initial studies to determine the effect and impact on diagnostic accuracy of PET/MR, and how clinical PET/MR protocols can be designed effectively in terms of imaging.

"We are beginning to replace some PET/CT studies on patients with head and neck cancers with PET/MR, and we are very confident that trend will continue," he explains. "We also think we can partly replace PET/CT for melanoma and imaging brain cancers. These are all indications where we typically have these patients undergo PET/CT and an MR anyway, so PET/MR could be an ideal one-stop shop imaging approach."

With an integrated PET/MR scan, it is possible for the clinician to rule out or rule in metastatic disease, Dr. Veit-Haibach says, and that will alter the way patients are treated. In the liver, it is possible that PET/MR may be able to image more metastases, as MR is an excellent tool for imaging this organ.

Dr. Veit-Haibach's area of expertise is oncology, and he already performs multi-parametric imaging with MR. He sees tremendous potential for contrast and even non-contrast MR perfusion to provide the metabolic information needed in hyperfractionated radiation therapy. Armed with the information from this study, it may be possible to

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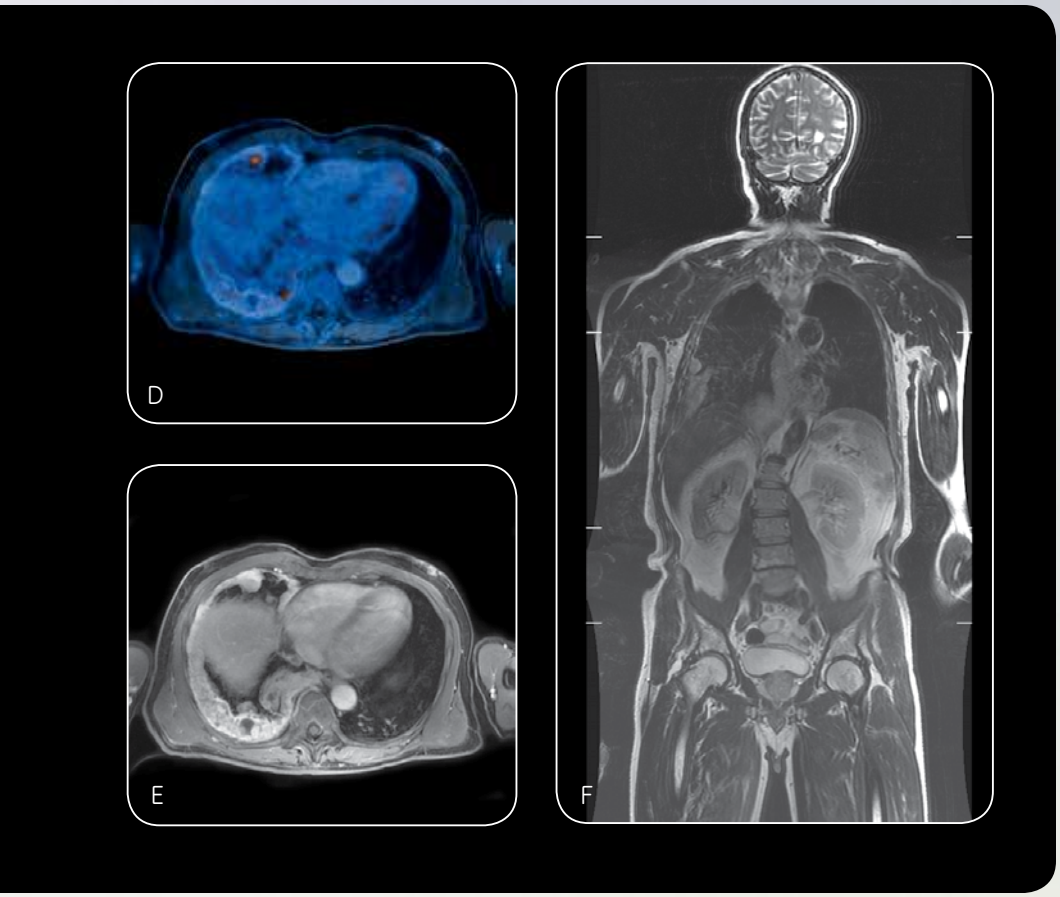

better identify necrotic centers of a tumor and then plan for a boost in radiation to that area.

Research on neurodegenerative diseases may also benefit from PET/MR, he adds. Preliminary studies have shown that intravenous immunoglobulin (IVIG) products and amyloid beta (Aβor Abeta) peptides may stabilize Alzheimer's patients. If these initial results are proven over the long term, then the images generated from PET/MR scanning could play an important role in future research and clinical evaluations.

While clinical evaluations are important, there is another aspect of PET/MR that USZ has been working on: optimizing PET/MR workflow. "We are evaluating the MR sequences used in a PET/MR study," Dr. Veit-Haibach explains. Many of the PET/MR protocols in the literature, he says, are just MR protocols transferred to PET/MR. The key question is how to tailor MR protocols to PET/MR studies and still achieve excellent diagnostic accuracy that is as good, or better, than PET/CT.

"We have already published our findings that we can use a basic PET/MR protocol, more or less in the same time as a PET/CT study—approximately 15 minutes—for evaluating metastatic patients with just three whole body sequences," he explains. The study consists of whole body T1, T2, and a respiratory-gated sequence for the chest; other sequences, he says, can be skipped. As another example, Dr. Veit-Haibach says he feels that in certain indications, such as head and neck cancers, MR diffusion imaging is not needed, as PET can provide the relevant information.

Even with the work that needs to be done on optimizing the workflow, Dr. Veit-Haiback is pleased with the initial imaging results of the SIGNA PET/MR. "The image quality and sensitivity is generally quite good, although we have three years of experience with the Discovery MR750w so that was nothing new to us. However, the PET time-of-flight in a PET/MR system is unrivaled in the industry, it is very good. We did some measurement of the PET sensitivity, and found the PET component to be excellent. The PET sensitivity should translate to better diagnostic quality body imaging."

Figure 3. SIGNA PET/MR installed at University Hospital of Northern Sweden.

University Hospital of Northern Sweden

Since 2006, the University Hospital of Northern Sweden in Umeå, has been utilizing MR for radiation therapy planning, primarily for target delineation purposes. It has the largest oncology clinic in the region and treats all types of cancer with different types of therapy, including radiation therapy, chemotherapy, and antibody biological treatment. The hospital is a pioneer and leader in MR-based radiation therapy.

Over the last year, Björn Zackrisson, MD, Professor in the Department of Radiation Sciences, has been investigating the use of functional MR imaging for identifying the most aggressive tumors and predicting response to therapy. With the new SIGNA PET/MR system, he is exploring the combined use of functional MR and functional PET.

"The main purpose is the imaging of biomarkers for tumor aggressiveness and tumor response to treatment," Professor Zackrisson explains. The hybrid modality at Umeå will be used first in patients with brain lesions, prostate tumors, and squamous carcinoma.

Using diffusion weighted imaging and dynamic contrast-enhanced MR combined with the tracer uptake information from PET, Professor Zackrisson hopes to better define patients with head and neck cancers that are predictably good responders to therapy. "We can use this information for more personalized treatments, to avoid toxic chemotherapy with patients who don't need it, or to adapt the treatment by adding chemotherapy or increasing the dose to a specific sub volume of the tumor," he says.

Patrik Brynolfsson, PhD, Medical Physicist in the Department of Radiation Sciences at Umeå, explains that in the Discovery MR750w, the spine coils are fixed in the table, but in the PET/MR it is fixed in the bore. This presents the opportunity to overlap the coils in the head area. Patients are always imaged in the same position they will receive treatment, so mimicking that positioning in the PET/MR is critical.

One challenge moving from 1.5T to 3.0T is that it can be more difficult to obtain a homogeneous image due to the dielectric effect, adds Dr. Brynolfsson. "We also need accurate geometry corrections in larger fields of view," he explains. GE has provided Umeå with a large phantom to control geometric distortions and evaluate them.

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Figure 4. Head and neck and body coils for MR imaging on the SIGNA PET/MR system at Umeå.

However, even with this challenge the overall image quality is quite impressive, adds Dr. Brynolfsson. "We've started using FOCUS for diffusion imaging and it is a nice improvement from the typical diffusion weighted sequence," he says.

In addition to noting the quality of the head and neck imaging, the PET image quality is also very good says Joakim H. Jonsson, PhD, Medical Physicist in the Department of Radiation Sciences at Umeå. As the first PET/MR with time-of-flight, he sees the direct impact of this capability on the PET attenuation correction, which also impacts image quality. He believes more areas of research will be initiated with continued evaluation of the attenuation correction and time-of-flight on the PET imaging component. "It is important to look at this as a new field, not just a fancy MR, PET or even compare to PET/CT," he says. "This is very good technology that will continue to improve in a short period of time, so we have to think and explore new ways to utilize it."

Professor Zackrisson believes that one of the most exciting new areas warranting further research is the exploration of new PET tracers. While this is not yet on his roadmap, he sees PET/MR as playing a key role in tracer development.

It is clear from talking to the researchers at these three sites that the SIGNA PET/MR is a very capable new research and clinical tool, providing excellent image quality and ease of use. After just a few months, it is already opening up opportunities to further the medical field and enhance patient care.

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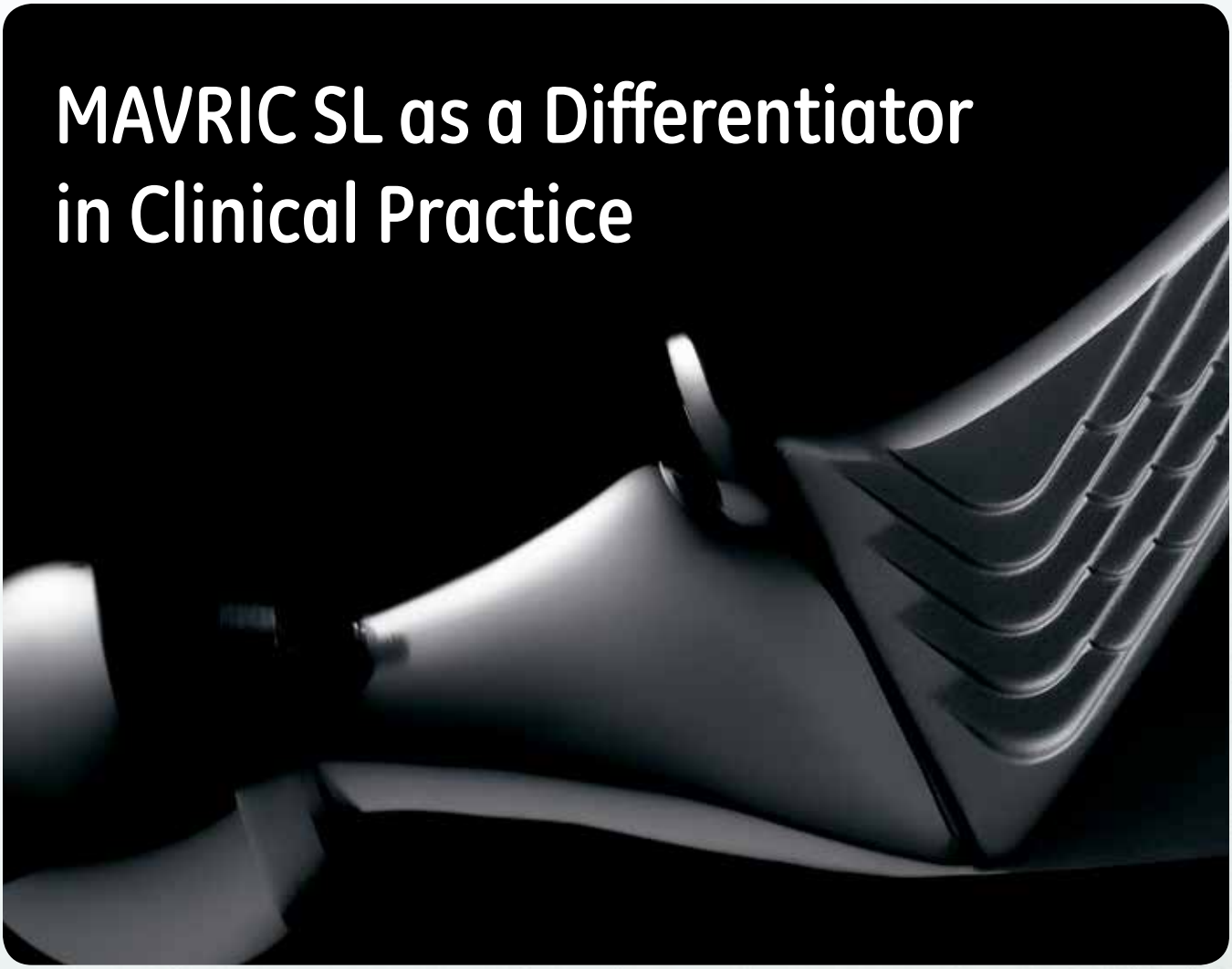
Håkan Ahlström, MD, *is Chairman, Department of Radiology, Oncology, Radiation Sciences and Professor of Radiology at Uppsala University Hospital. He received his medical degree from Uppsala and continues to supervise graduate and medical students at the University. Professor Ahlström is the author of 240 scientific articles published in international scientific peer reviewed journals and is currently the editor of the Uppsala Journal of Medical Sciences. Together with two other clinicians, he holds a patent on a bone biopsy system called Bonopty and has a patent pending for Imiomics.*

Björn Zackrisson, MD, *is a Professor in the Department of Radiation Sciences, at the University Hospital of Northern Sweden in Umeå. He also holds positions as Head of Research and Development and as a clinical consultant for radiotherapy in the hospital's Cancer Centre. Professor Zackrisson received his medical degree from Umeå University and is also certified as a specialist in oncology. He has been a principal investigator for several clinical studies and is Chairman of the scientific council for radiotherapy of the Swedish Radiation Safety Authority.*

MAVRIC SL as a Differentiator in Clinical Practice



By Kevin Koch, PhD, Associate Professor, Departments of Radiology and Biophysics, Rajeev Mannem, MD, Assistant Professor of Radiology, Scott Erickson, MD, Professor of Radiology, and Mark Hohenwalter, MD, Associate Professor of Radiology and Vice Chair of Education, Medical College of Wisconsin

It is now commonplace to refer patients with MR Conditional implants for MR clinical assessment. In addition, and with increasing frequency, the anatomic area of clinical interest is often in the immediate vicinity of the implanted hardware. Susceptibility artifacts generated by the implanted devices can substantially confound such assessments.

The most prominent susceptibility artifacts near MR Conditional implants arise from distorted slice-excitation planes and spatial displacements in the frequency-encoded in-plane dimension.

Historically, high pixel-bandwidth 2D fast-spin-echo (FSE) images have been utilized to mitigate susceptibility artifacts around implants. When combined with thin slices, which reduces the magnitude of slice-selective distortions, the technique is often referred to as the Metal-Artifact-Reduction Sequence or the "MARS" protocol. There is historically some nomenclature confusion in the clinical community on the nature of the MARS protocols. The original "MARS" acronym was employed in a published paper that utilized a more advanced

Figure 1. Coronal MARS image of stainless steel fixation screws at 1.5T (A). A hyperintensity artifact (blue arrow) is correlated with the slice pileup shown in the reformatted image (B, red arrow); slice selective dimension is in the vertical dimension.

technique know as View-Angle Tilting (VAT),[1,2] which will be discussed later in this article. However, recent clinical protocols and presentations often refer to "MARS" protocols that do not use VAT. VAT has only recently been cleared for clinical use on MR Conditional metal implants, whereas clinics have been using commercially available software to perform "MARS" protocols for decades. Here we distinguish MARS and MARS+VAT as separate sequences, which is consistent with the nomenclature currently used in the clinical community.

Under a routine MARS protocol, a voxel near an implant that is 4 kHz off-resonance will still be displaced four slice-widths in the slice-selective dimension and roughly eight voxels in the frequency-encoded direction. For typical voxels of 2.5mm slice thickness and 0.5mm in-plane resolution, this yields a resultant distortion of roughly 12mm. In addition, the warping of slice profiles can generate distinctive hyperintensities in images, where multiple slice-widths are effectively superimposed onto one another. These "pileup" hyperintensity artifacts are also found in the frequency encoded dimension, but are typically much more prominent in the slice-selective dimension. Figure 1 shows MARS images acquired on a subject with stainless steel fixation screws at 1.5T. An axial reformat (Figure 1B) of the coronal acquisition shows the clear warping of selected slices that generates observed hyperintense artifacts in the reformatted (red arrows) and in-plane (blue arrow) images.

In order to further reduce these artifacts, the aforementioned VAT method, which was originally devised to reduce chemical shift artifacts,[1] was applied to the metal artifact problem.[2] VAT reduces frequency-encoded distortions by constraining the maximum off-resonance experienced by any encoded spin to one-half of the applied radio-frequency bandwidth. This reduces bulk displacements in the frequency-encoded dimension. VAT can be used in conjunction with MARS protocols. However, VAT does not address slice-selective distortions, nor does it address pileup artifacts in either the slice-selective or frequency-encoded dimensions. As a result, MARS+VAT images often show similar levels of artifact as MARS images.

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To exemplify the limited impact of VAT in reducing bulk image artifacts, consider the previously analyzed voxel resonating at 4 kHz off-resonance. When including VAT in the MARS protocol, the net displacement of this voxel is only reduced to 10mm from the original 12mm displacement using only MARS. This is because 10mm of the displacement in the MARS image was due to slice-selective warping and only 2mm of displacement was due to frequency-encoded distortions. In this case, VAT would improve the net displacement of the voxel in question by less than 20%.

Three-dimensional multi-spectral imaging (3D-MSI) was developed to provide a more substantial alternative to susceptibility artifact reduction near metal implants. There are two broad approaches to 3D-MSI, which are generally known as MAVRIC[3] and SEMAC.[4] Both MAVRIC and SEMAC reduce susceptibility artifacts by limiting off-resonance distortions to discretely applied RF excitation windows and utilizing phase-encoding instead of slice-selection processes. Referring again to the previous example of a voxel resonating at 4 kHz off-resonance, a typical 3D-MSI acquisition will reduce the total displacement to roughly 1mm, compared to the total displacement of 10mm for MARS+VAT and 12mm for MARS.

Like MARS and VAT, 3D-MSI cannot eliminate pileup artifacts in the frequency encoded direction. In the plurality of individual spectral images that are combined in 3D-MSI techniques, residual pileup artifacts manifest as concentric rings near implant interfaces. A substantial difference between the MAVRIC and SEMAC approaches to 3D-MSI is the heavy overlap of spectral image windows utilized in the MAVRIC approach.[5] This overlap substantially reduces the conspicuity of residual pileup artifacts. Despite these advantages, a significant limitation with the MAVRIC method is its lack of slab-selectivity, which generates wrap artifacts in hip, spine, and shoulder exams.[5]

MAVRIC SL, GE Healthcare's technique cleared for imaging around MR Conditional implants, is a third approach to 3D-MSI that represents an evolution of the concepts originating in the MAVRIC and SEMAC methods. By merging the spectral strategy of MAVRIC and the slab-selectivity of SEMAC, MAVRIC SL provides an efficient, practical, and minimal-artifact approach for MR imaging around MR Conditional implants.[5] MAVRIC SL applies a generalized 3D extension of the VAT principle to add slab-selectivity to overlapping spectral bins utilized in the non-selective MAVRIC 3D-MSI approach. In addition, the architecture of MAVRIC SL provides an efficient means to distribute an arbitrary number of pre-defined spectral images across 3D-MSI acquisitions.[6] This application design enables flexible image contrasts and improves the acquisition SNR efficiency.

In this article, we demonstrate Proton-Density (PD), STIR, and T1-weighted (T1w) image contrasts, which are commercially available and indicated for use on MR Conditional implants.

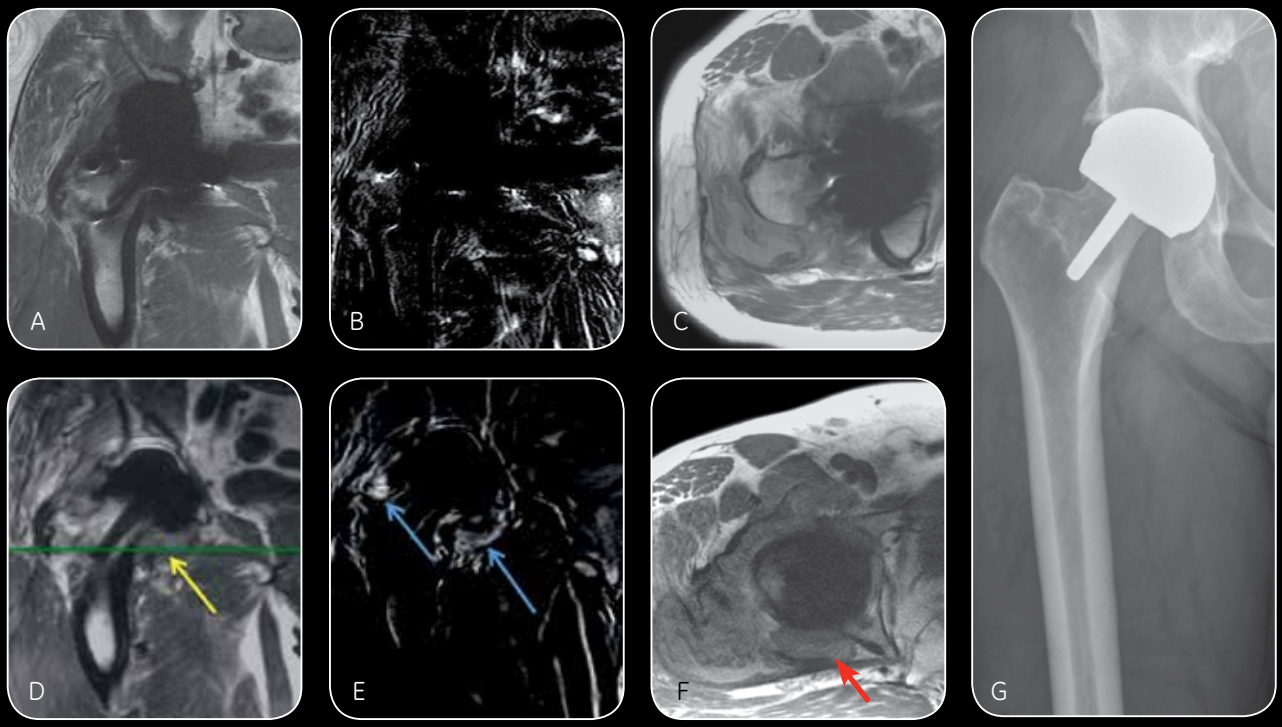

Figure 2. MARS (A-C) and MAVRIC SL (D-F) images of a hip resurfacing implant at 1.5T. The use of MAVRIC SL clearly visualizes regions of adverse local tissue reaction (arrows) in the T1w (D), contrast-subtracted (E), and proton density weighted (F) images. Implant is clearly visualized in the radiograph (G).

Clinical Case 1

Figure 2 presents images of a symptomatic patient instrumented with a cobalt-chromium hip resurfacing implant. T1w MARS and T1w MAVRIC SL are shown in (Figure 2A) and (Figure 2D) respectively. The MR Conditional implant interface is clearly visualized in the MAVRIC SL image, as indicated in the accompanying radiograph (Figure 2G). The yellow arrow indicates an adverse local tissue reaction that is not visible in the MARS image (Figure 2A). After gadolinium contrast injection, delayed enhancement difference images are shown for T1w MARS (Figure 2B) and T1w MAVRIC SL (Figure 2C). In the MAVRIC SL difference image (Figure 2E), gadolinium uptake is clearly visualized in ALTR regions near the implant interface (blue arrows) that are obscured by artifact in the MARS difference image (Figure 2B). An axial (scan plane indicated in Figure 2D) PD MAVRIC SL image (Figure 2F) clearly indicates the adverse local tissue reaction (red arrow). A substantial portion of the reaction is obscured in the axial PD MARS image (Figure 2C). Following the severe ALTR assessment provided by these images, the patient was referred for total joint replacement.

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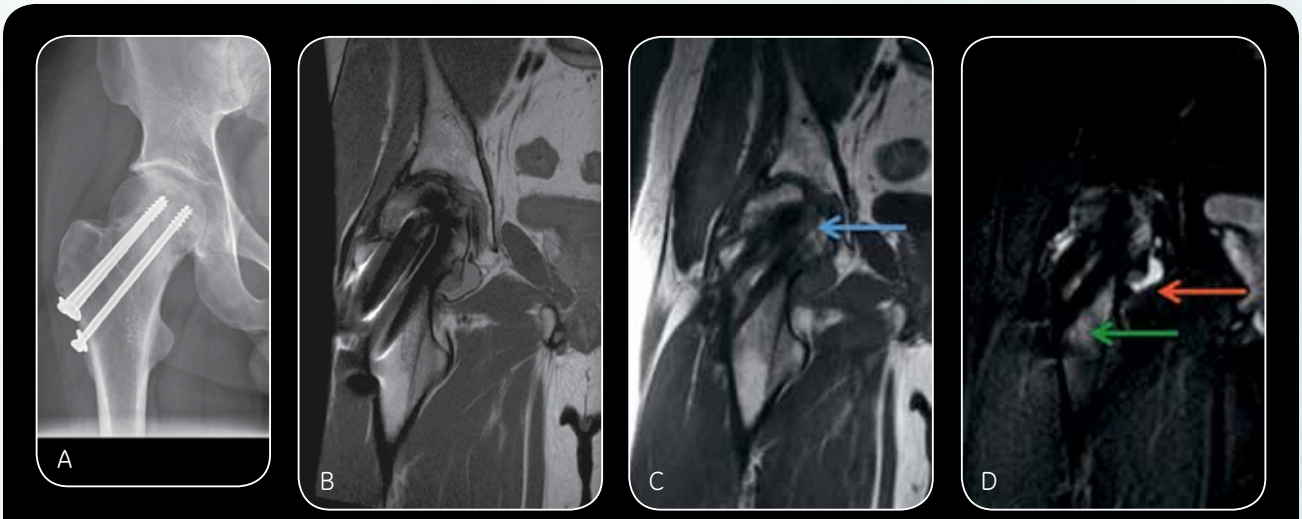

Figure 3. Radiograph (A), MARS (B), and MAVRIC SL (C-D) images of fixation screws at 1.5T. The use of MAVRIC SL clearly visualizes necrosis (blue arrow) in the T1w image (C), along with fluid buildup (red arrow) and widespread edema (green arrow) in the STIR image (D).

Clinical Case 2

Figure 3 displays images of a symptomatic patient instrumented with stainless steel fixation screws used to repair a femoral fracture. A radiograph of the instrumented joint is shown in Figure 3A. T1w MARS and T1w MAVRIC SL images are shown in Figure 3B and Figure 3C, respectively. Avascular necrosis is clearly indicated (blue arrow) in the MAVRIC SL image (Figure 3C), but is nearly completely obscured by artifact in the MARS image (Figure 3B). A MAVRIC SL STIR image (Figure 3D) demonstrates widespread edema throughout the femoral head (green arrow) and a fluid collection inferior to the necrotic bone. Following the avascular necrosis assessment provided by these images, the patient was referred for total joint replacement.

Clinical Case 3

MAVRIC SL can also be useful for assessment of symptomatic total knee replacements. Figure 4 shows images of a patient reporting significant pain in the patellar region. A radiograph of the knee implant is shown in Figure 4E. Proton-density weighted MARS and MAVRIC SL STIR images are shown in Figure 4A and Figure 4B, respectively. The severe disruptions of assessment near the implant are clearly visualized in the MARS image (Figure 4A). In the MAVRIC SL STIR image (Figure 4B), pockets of fluid in the patellar region, the joint space, and under the tibial stem are clearly identified (blue arrows). In addition, femoral osteolysis (red arrow) is clearly identified in a different location on the MAVRIC SL proton density image (Figure 4D). This region of osteolysis is clearly lost on the correlated MARS image (Figure 4C).

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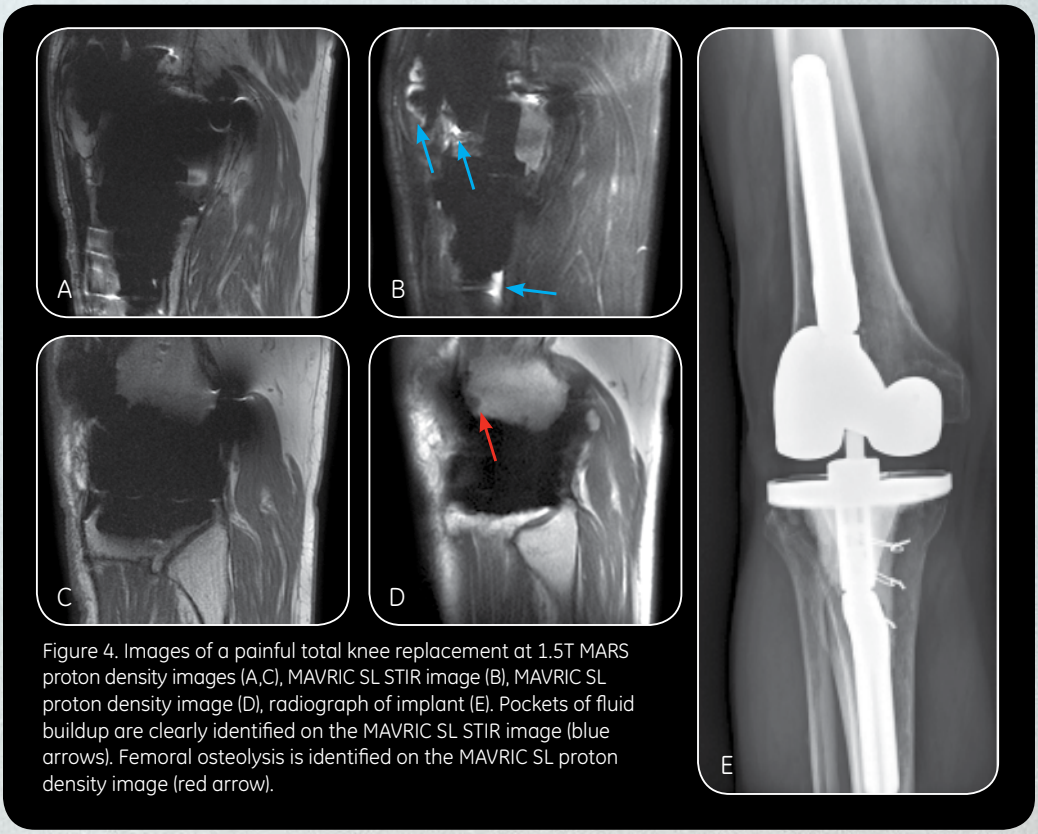


Figure 4. Images of a painful total knee replacement at 1.5T MARS proton density images (A,C), MAVRIC SL STIR image (B), MAVRIC SL proton density image (D), radiograph of implant (E). Pockets of fluid buildup are clearly identified on the MAVRIC SL STIR image (blue arrows). Femoral osteolysis is identified on the MAVRIC SL proton density image (red arrow).

Conclusion

The preceding clinical examples demonstrate that judicious use of the multiple image contrasts feasible with MAVRIC SL can enable a variety of diagnostic capabilities that were previously unattainable with MARS or MARS+VAT technologies. A key component of these differentiating capabilities is the ability to assess images in the immediate vicinity of implant interfaces. The successful mitigation of most artifacts in these regions has generated more confidence in the ability of MR to help identify the source of a variety of conditions in patients with MR Conditional implants referred for diagnostic imaging.

References

1. Cho Z, Kim D, Kim Y. Total inhomogeneity correction including chemical shifts and susceptibility by view angle tilting. Med Phys 1988; 15:7–11.
2. Olsen RV, Munk PL, Lee MJ, et al. Metal artifact reduction sequence: early clinical applications. RadioGraphics 2000; 20:699–712.
3. Koch KM, Lorbiecki JE, Hinks RS, King KF. A multispectral three-dimensional acquisition technique for imaging near metal implants. Magn Reson Med 2009; 61:381–390.
4. Lu W, Pauly KB, Gold GE, Pauly JM, Hargreaves BA. SEMAC: slice encoding for metal artifact correction in MRI. Magn Reson Med 2009; 62: 66–76.
5. Koch KM, Brau ACS, Chen W, Gold G, Hargreaves B, Koff M, Potter P, and King K. Imaging near metal with a MAVRIC-SEMAC hybrid. Magn Reson Med 2011; 65:71–82.
6. Koch KM, Koff MF, Shah PH, Kanwischer A, Gui D, Potter HG, Flexible longitudinal magnetization contrast in spectrally overlapped 3D-MSI metal artifact reduction sequences: Technical considerations and clinical impact, Magn. Reson Med 2015, DOI: 10.1002/mrm.25518.

Kevin Koch, PhD, *is an Associate Professor appointed in the departments of Biophysics and Radiology at the Medical College of Wisconsin in Milwaukee, WI. Dr. Koch's work focuses on solving technical challenges in clinical MR applications. He has been working for over eight years on reducing metal artifacts in MR, particularly focusing on 3D-MSI technical development and clinical application.*

Rajeev Mannem, MD, *is an Assistant Professor of Radiology at the Medical College of Wisconsin in Milwaukee, WI. Dr. Mannem's clinical specialty is in body and musculoskeletal MR. Dr. Mannem is currently engaged in research investigations targeting advanced use of 3D-MSI in the clinic.*

Scott Erickson, MD, *is a Professor of Radiology at the Medical College of Wisconsin in Milwaukee, WI. Dr. Erickson's clinical specialty is in body and musculoskeletal MR. Erickson is currently engaged in research investigations targeting advanced use of 3D-MSI in the clinic.*

Mark Hohenwalter, MD, *is an Associate Professor of Radiology at the Medical College of Wisconsin in Milwaukee, WI. Dr. Hohenwalter is the Director of Body and Musculoskeletal MRI as well as the Vice Chair of Education at the Medical College of Wisconsin. Dr. Hohenwalter is currently engaged in research investigations targeting advanced use of 3D-MSI in the clinic.*

The Medical College of Wisconsin *is a private, freestanding medical school and graduate school of sciences located in Milwaukee.*

Whole Body MR for Visualizing Metastatic Prostate Cancer

Prostate cancer is the second most common cancer in men worldwide, accounting for 15% of all new cancer cases.[1] Great strides have been made in the detection of prostate cancer and corresponding drop in mortality rates due to the introduction of the prostate specific antigen (PSA) test in the late 1980s. This test has led to a 65% reduction in men being initially diagnosed with metastatic cancer due to early detection of the disease.[2] But metastatic disease remains a major therapeutic challenge.

> "Whole body MR is gaining interest and acceptance as a tool for lesion visualization in metastatic cancer and hematologic malignancies."
>
> *Professor Frederic Lecouvet*

Frederic Lecouvet, MD, PhD,
is a Professor of Radiology and Head of the MRI Unit in the Radiology Department at the Cliniques Universitaires Saint Luc, Université Catholique de Louvain, in Brussels, Belgium.

Patients with metastatic disease may benefit from recent advances in therapy e.g., chemotherapy, novel endocrine agents, and immunotherapy, which may allow a significant prolongation of survival but also help to improve quality of life. These modern treatments require optimal metastases detection before their initiation, and monitoring of their efficacy by evaluation of lesion response to help the clinician in the sequencing of these drugs.

While MR is now routinely utilized by clinicians in determining a diagnosis and studying the localized extent of prostate cancer, Frederic Lecouvet, MD, PhD, Professor of Radiology and Head of the MRI Unit in the Radiology Department at the Cliniques Universitaires Saint Luc, Université Catholique de Louvain (UCL), in Brussels, believes that whole body MR is an excellent tool for visualizing metastatic disease and is one of the more promising tools that assists the clinician in determining the global extent of the disease.

"Whole body MR is gaining interest and acceptance as a tool for lesion visualization in metastatic cancer and hematologic malignancies," says Professor Lecouvet. Metastatic prostate cancer most often manifests in the bones and lymph nodes.

A 2012 study published in *European Urology* by Professor Lecouvet and colleagues examined the use of whole body MR with DWI as a potential single-test for detecting metastatic prostate cancer compared to using both scintigraphy and CT as the other visualization tools. The authors concluded that whole body MR outperformed scintigraphy in more clearly allowing the identification of bone metastases and performed as well as CT in helping clinicians with their evaluation of enlarged lymph nodes.[3]

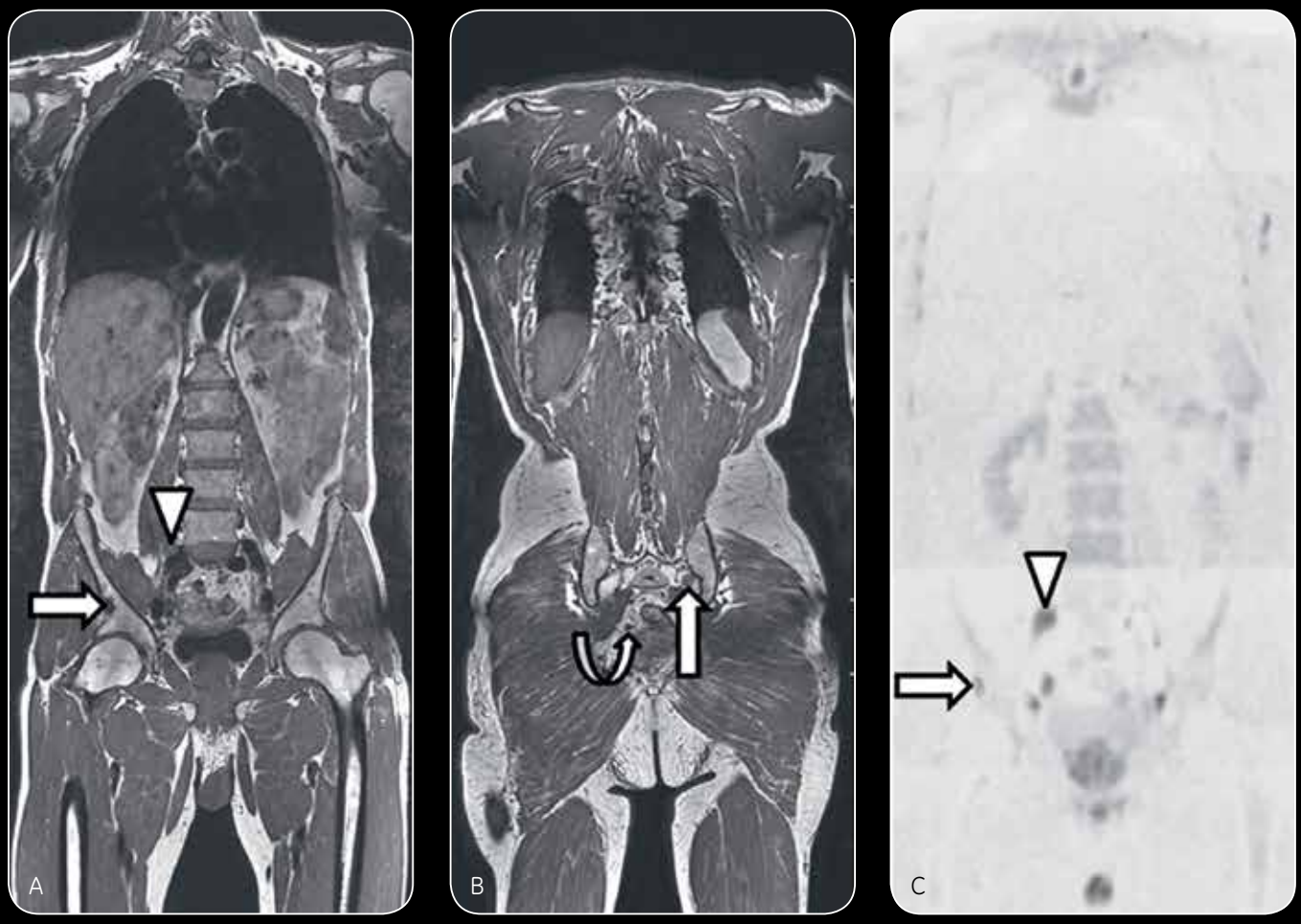


Figure 1. A whole-body MR examination including anatomic T1 and functional DWI MR sequences in a patient in his 60s with newly diagnosed prostate cancer (time of acquisition: 24 minutes). Coronal whole body T1 images (A, B) show right iliac and left sacral bone metastases (arrows) and right iliac (arrowhead) and pararectal (curved arrow) node metastases. The bone (arrows) and node (arrowhead and curved arrow) are evident on whole body DWI images (C, D).

The lack of specificity and sensitivity of the routinely used methods to diagnose metastases of prostate cancer is well described in the literature, adds Professor Lecouvet. "Benign bone lesions, fractures, inflammatory or degenerative joint disease may cause false positive observations," he says. "When it comes to lack of sensitivity, more recent imaging techniques, such as MR and choline PET, have shown that negative observations from previously used imaging modalities could ignore significant lesions. This could have major therapeutic implications." For example, a patient with newly diagnosed prostate cancer and a false negative metastatic work-up could unnecessarily undergo a prostatectomy when, in fact, he has metastatic prostate cancer that requires a different (i.e. systemic) treatment regimen, Professor Lecouvet explains.

"Whole body MR that includes anatomic, most often T1- and STIR-weighted images, and functional sequences, diffusion-weighted images, offers the opportunity to target all metastases—both bone and lymph nodes—using only one examination," says Professor Lecouvet. "Whole body MR is an effective tool we use to obtain a clear extent of the metastatic disease in order to determine treatment planning decisions. There are other patient

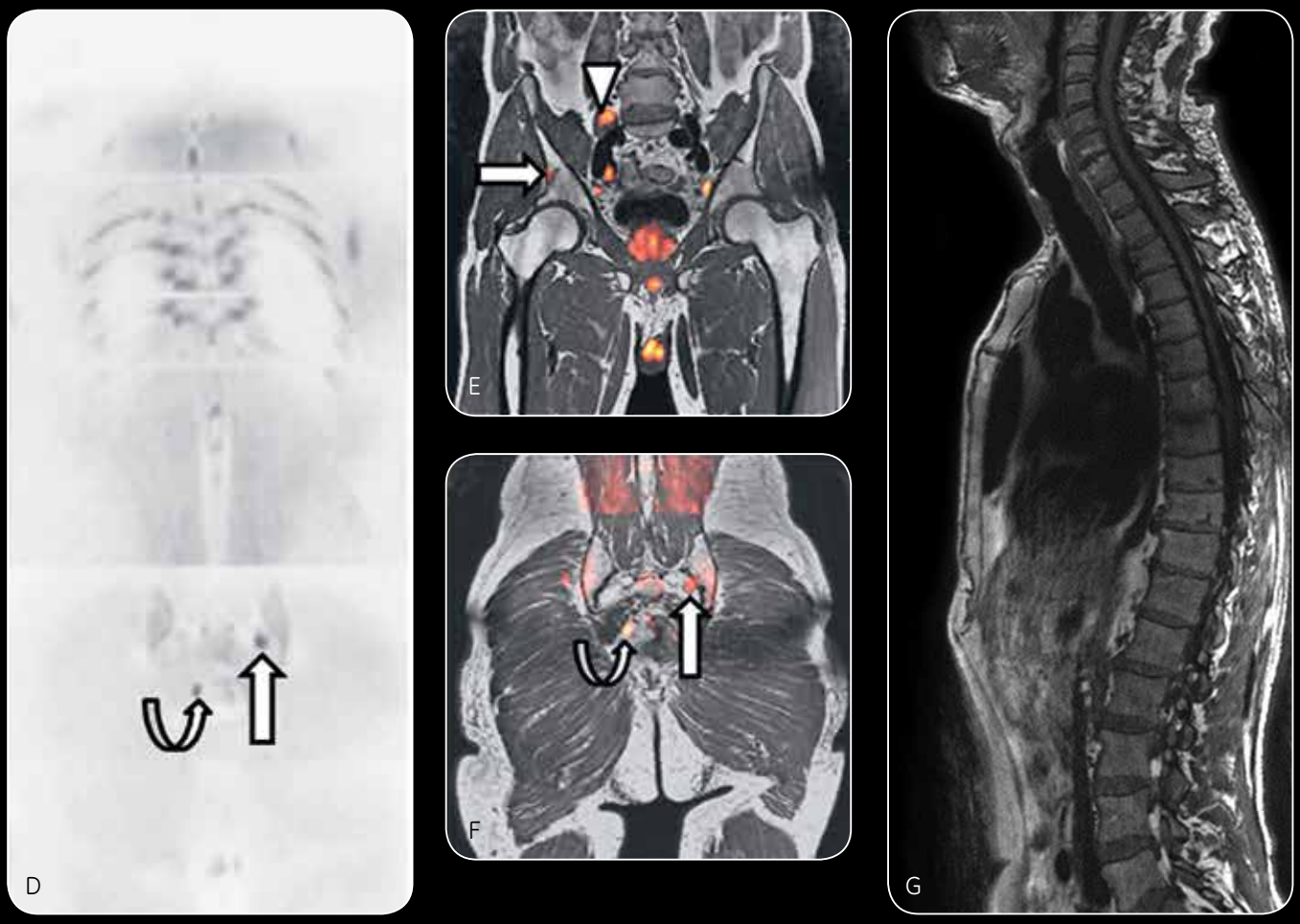


Figure 1 (cont.). Fused T1 and DWI images clearly illustrate the lesions (E, F). Sagittal reformatted slice enables reliable study of the spine showing no metastases in this case (G).

benefits as well," he explains. "The patients are provided with optimal information on the metastases in one step.

While Professor Lecouvet is very excited at the potential for utilizing whole body MR with DWI, he also envisions a bright future for the use of 3D (at this time T1-weighted) MR sequences as the primary anatomic imaging component of an MR examination to assist clinicians in their evaluation of metastatic prostate cancer.

As reported by Professor Lecouvet and his colleagues in the April, 2015, issue of *Radiology*, 3D T1-weighted MR provides significantly better SNR and CNR compared with 2D MR sequences. With 3D T1-weighted, the authors reported it was as good or better for visualizing bone metastases and captured "significantly more node metastases as well as significantly more node-positive patients," compared to whole body 2D sequences. In particular, 3D MR enabled the clinicians to evaluate areas that are typically difficult to study with conventional 2D sequences, such as the ribs, sternum, skull, abdomen/pelvis, and posterior vertebral elements.[4]

"Scientific evaluation of the value of 3D compared to 2D sequences has shown improvements in terms of signal, thin sections, and multiplanar reconstructions," Professor Lecouvet explains. In addition to detection with 3D T1-weighted, it is possible to accurately delineate the precise

> "The ability of whole body MR to overcome the challenges that other imaging methods may have, such as bone scintigraphy, is transposable to imaging hematologic cancers, such as multiple myeloma, where whole body MR challenges radiographic skeletal surveys and has been shown to outperform for lesion detection."
>
> *Professor Frederic Lecouvet*

location of the lesion and obtain measurements. This capability is as important for treatment monitoring; anatomic MR sequences offer a high sensitivity for evaluating treatment-induced changes, especially in lesion size, and are a helpful tool for the clinician in determining if the lesion responds, is stable, or progresses during the course of therapy.[5] This is particularly useful for metastatic prostate cancer, where there are a variety of drugs that may be successively introduced in cases where there is a lack of response to treatment."

A 3D MR sequence also provides the ability to shorten scan time by avoiding the repetition of imaging planes and reduces partial volume effects that can occur with thicker image slices and intersection gaps, he adds. At UCL, the implementation of whole body MR, including 3D T1-weighted and DWI sequences, on the facility's Optima™ MR450w system for bone and node visualization in prostate cancer patients at high risk for metastases are completed in less than 30 min.

While Professor Lecouvet acknowledges that the lack of reimbursement in some countries for whole body MR may initially limit its utilization, he believes the overall potential financial benefit can outweigh the initial imaging costs. "Its cost might be attractive compared to the sum of other, less effective examinations used for visualizing lesions," he says. Add to this the cost of unsuccessfully treating a patient for a primary tumor when they have metastatic disease, or continuing expensive and potentially toxic treatment that may not be effective, and the health economic benefits can be staggering.

"The ability of whole body MR to overcome the challenges that other imaging methods may have, such as bone scintigraphy, is transposable to imaging hematologic cancers, such as multiple myeloma, where whole body MR challenges radiographic skeletal surveys and has been shown to outperform for lesion detection," he adds.[6] Professor Lecouvet also sees potential use of MR in evaluating lymphoma, where whole body MR can challenge FDG PET for bone and soft tissue lesion detection, and metastatic breast cancer, which like prostate cancer often metastasizes to the bone.

As a result of Professor Lecouvet's work and others in the field, whole body MR utilizing both functional DWI and morphologic 3D T1-weighted sequences could become an ideal, one-step imaging test for metastases imaging in patients with prostate cancer.

References.

1. World Cancer Research Fund International.
2. Aus G, Bergdahl S, Lodding P, Lilja H, Hugosson J. Prostate cancer screening decreases the absolute risk of being diagnosed with advanced prostate cancer—results from a prospective, population based randomized controlled trial. Eur Urol 2007;51:659–64.
3. Lecouvet, FE, El Mouedden J, Collette L, et al. Can Whole-body Magnetic Resonance Imaging with Diffusion-weighted Imaging Replace Tc 99m Bone Scanning and Computed Tomography for Single-step Detection of Metastases in Patients with High-risk Prostate Cancer? European Urology 62, 68–75 (2012).
4. Pasoglou, V, Michoux N, Peeters F, et al. Whole-Body 3D T1-weighted MR Imaging in Patients with Prostate Cancer: Feasibility and Evaluation in Screening for Metastatic Disease. Radiology 141242 (2014).
5. Lecouvet, FE, Larbi A, Pasoglou V, et al. MRI for response assessment in metastatic bone disease. European Radiology 2013; 23:1986–1997.
6. Dimopoulos, MA, Hillengass J, Usmani S,et al. Role of magnetic resonance imaging in the management of patients with multiple myeloma: a consensus statement. J. Clin. Oncol, 2015; 33:657–664.

Frederic Lecouvet, MD, PhD, *is a Professor of Radiology and Head of the MRI Unit in the Radiology Department at the Cliniques Universitaires Saint Luc, Université Catholique de Louvain (UCL) in, Brussels, Belgium. He completed both his medical training and PhD at the UCL and has held many specialist teaching appointments focusing on imaging and specifically the use of MRI. Professor Lecouvet's areas of expertise include imaging of the spine, joint and cartilage, orthopedic, rheumatologic and oncologic conditions, particularly bone tumors and metastases, and assessing response of lesions to modern treatments. Imaging in cancer and metastatic disease is one of the main fields of development for his research projects.*

Two Facilities, One Goal

Direct Investigator Access to MR Image Reconstruction Environment Opens New Research Doors

Along with the continued push to develop breakthrough MR applications comes the need for researchers to have comprehensive access to both pulse sequence and image reconstruction environments. While researchers have been able to design and implement their pulse sequences to run on a MR scanner for many years, exploring innovative and customer-based image reconstruction ideas and generating "readily presentable" images has always been a challenge.

GE Healthcare's new Orchestra Software Development Kit (SDK)‡ now gives customers direct access to GE's image reconstruction environment, helping them develop novel reconstruction algorithms in greatly reduced time and with much more consistent results.

The Orchestra SDK allows researchers to implement the same image reconstruction routines that are utilized in a GE MR scanner on any computing platform of their choice; however hardware and software system requirements and recommendations should be followed to support development. Through convenient MATLAB® and C++ interfaces, researchers can now apply their image reconstruction algorithms to the raw data from a scanner and incorporate many previously inaccessible but essential image reconstruction features. Examples of these include image un-aliasing with GE's parallel imaging routines (ASSET and ARC), correction for gradient non-linearities (GradWarp), insertion of DICOM images into the scanner database, and much more. The Orchestra SDK also includes reconstruction examples from EPI to Spectroscopy, and online help to get

‡Orchestra SDK is not a medical device and not intended to treat, diagnose, nor cure any disease or condition. To be used for research purposes only.

> "Previously, the options for processing the data in an alternate way were very limited. Even while sitting on the scanner, there were many things that could not be done. Because Orchestra is offline, researchers are not forced to sit at a scanner and play with settings in order to try and get the desired images. I want to be able to pull raw data and work on a reconstruction algorithm wherever I might be."
>
> *Dr. Kevin Koch*

users started—and the entire package is available through a new customer collaboration portal for GE research customers.

Medical College of Wisconsin

Kevin Koch, PhD, Associate Professor, Department of Biophysics and Radiology at the Medical College of Wisconsin in Milwaukee, WI, is leading two research projects that are heavily dependent on having access to the Orchestra SDK's reconstruction tools.

"These projects would have been very difficult to accomplish before Orchestra, because we did not have access to the algorithms that would allow us to examine the data offline and put it back together to refine our algorithms consistently with GE's product reconstruction," says Dr. Koch. "Currently, one of our big areas of interest is to make the acquisition as efficient as possible in order to improve the SNR and reduce scan time."

The first project involves reducing susceptibility artifacts using GE Healthcare's MAVRIC SL—a sequence for imaging soft tissue and bone near MR Conditional and MR Safe metallic implants. To conduct his research effectively, Dr. Koch needs the ability to alter the pulse sequence acquisition and build new reconstruction processing algorithms from the data pipelines. He is also utilizing the tool to aid in adding new contrast mechanisms to MAVRIC SL and improve the way fat signal is saturated, which is typically very difficult to do around metal implants. "We now have some very new ideas on how to reprocess the MAVRIC SL data in order to try and improve fat saturation."

The Orchestra SDK is having the same positive influence on Dr. Koch's brain imaging project—Quantitative Susceptibility Mapping (part of the GE/NFL Head Health Initiative)—which focuses on traumatic brain injury research and brain cancer. In this project, he has to utilize data from the SWAN neuro application and apply new processing algorithms to it. "In order to make my prototype clinically viable, I had to change the standard SWAN-like pulse sequence and do some unconventional things with it. I needed the Orchestra reconstruction to allow me to put that data back together so I could refine the algorithms utilized in this technology."

Dr. Koch says that facilities are often compelled to build their own imaging software prototypes. "Researchers need a lot of infrastructure to process the data and do something equivalent to the manufacturer. Until now, they had to do that on their own. Orchestra significantly lowers the barrier of entry for those who want to embark on their own research project."

Additionally, having access to algorithms is crucial, says Dr. Koch. "The Orchestra code is so well commented that researchers are now learning the workflow of the algorithms. This gives them an understanding for how the reconstruction of algorithms are put together, and how the final images are processed. Plus, they are learning a lot just from the comments that are in the code itself. Orchestra really adds to the education of researchers."

Kevin Koch, PhD,
is an Associate Professor in the Department of Biophysics and Radiology at the Medical College of Wisconsin in Milwaukee, WI.

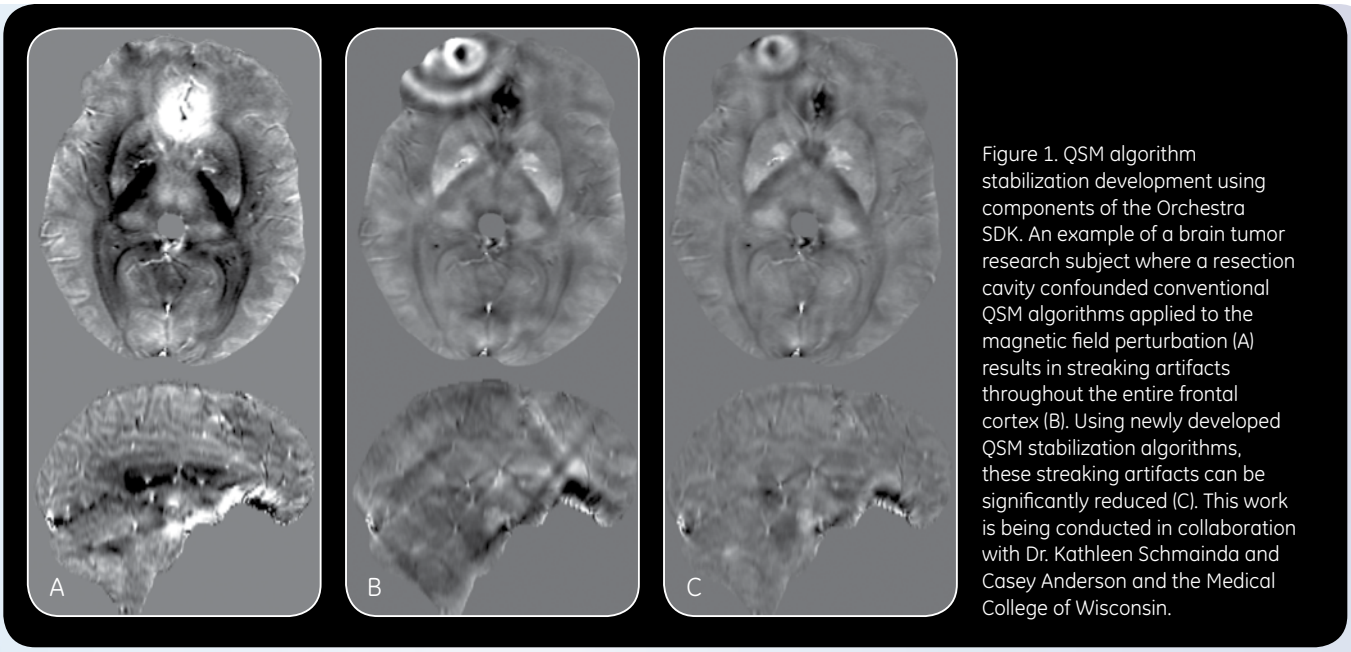


Figure 1. QSM algorithm stabilization development using components of the Orchestra SDK. An example of a brain tumor research subject where a resection cavity confounded conventional QSM algorithms applied to the magnetic field perturbation (A) results in streaking artifacts throughout the entire frontal cortex (B). Using newly developed QSM stabilization algorithms, these streaking artifacts can be significantly reduced (C). This work is being conducted in collaboration with Dr. Kathleen Schmainda and Casey Anderson and the Medical College of Wisconsin.

Because of this, Dr. Koch feels that the industry can expect to see an uptick in research efforts and development. Those who previously did not pursue an endeavor because of a lack of infrastructure or knowledge of the reconstruction algorithm might be enticed to move forward now. "The software design is streamlined, and the MATLAB interface is very easy to use. That's the real power of it—it does not have to be somebody who's an expert programmer in C or C++."

Another benefit: Researchers and clinicians no longer need to be tied to the workstation or scanner. "Previously, the options for processing the data in an alternate way were very limited. Even while sitting on the scanner, there were many things that could not be done. Because Orchestra is offline, researchers are not forced to sit at a scanner and adjust settings in order to try and get the desired images. I want to be able to pull raw data and work on a reconstruction algorithm wherever I might be," comments Dr. Koch.

Furthermore, Dr. Koch is pleased that the software is available on the Apple Macintosh® platform. "The fact that this is available on my development platform of choice makes the workflow so much easier. It's also available on on Linux and Windows, so it does not matter what platform a researcher is using... that provides freedom and flexibility."

The Orchestra SDK Customer Collaboration Portal, https://collaborate.mr.gehealthcare.com, is the primary way users can obtain the Orchestra SDK and then engage collaboratively with other clinicians and representatives at GE. The interactive portal is open to anyone with a GE MR system. Dr. Koch uses the portal and says, "The management of questions has been amazingly efficient. I think that's been crucial to the success of Orchestra, because without the quick feedback, it could be tough for some researchers to get off the ground—especially on some of the more detailed projects and pipelines. The responsiveness to questions on the portal makes access to the tool kit a lot easier and more streamlined."

At the Medical College of Wisconsin, Dr. Koch is assisting with six in-process projects that are heavily basing their research pipelines off of the Orchestra SDK; projects that likely would not have taken flight as quickly without the tool kit. In addition to the Quantitative Susceptibility Mapping and MAVRIC SL projects, he and his collaborators are utilizing Orchestra in several other projects.

Dr. Koch offers this advice to his peers: "Get engaged on the collaboration portal, since the GE development team is extremely responsive. I have even been encouraging our students and researchers to go to the portal if they have a question that's even remotely difficult, because the experts will provide an answer quickly."

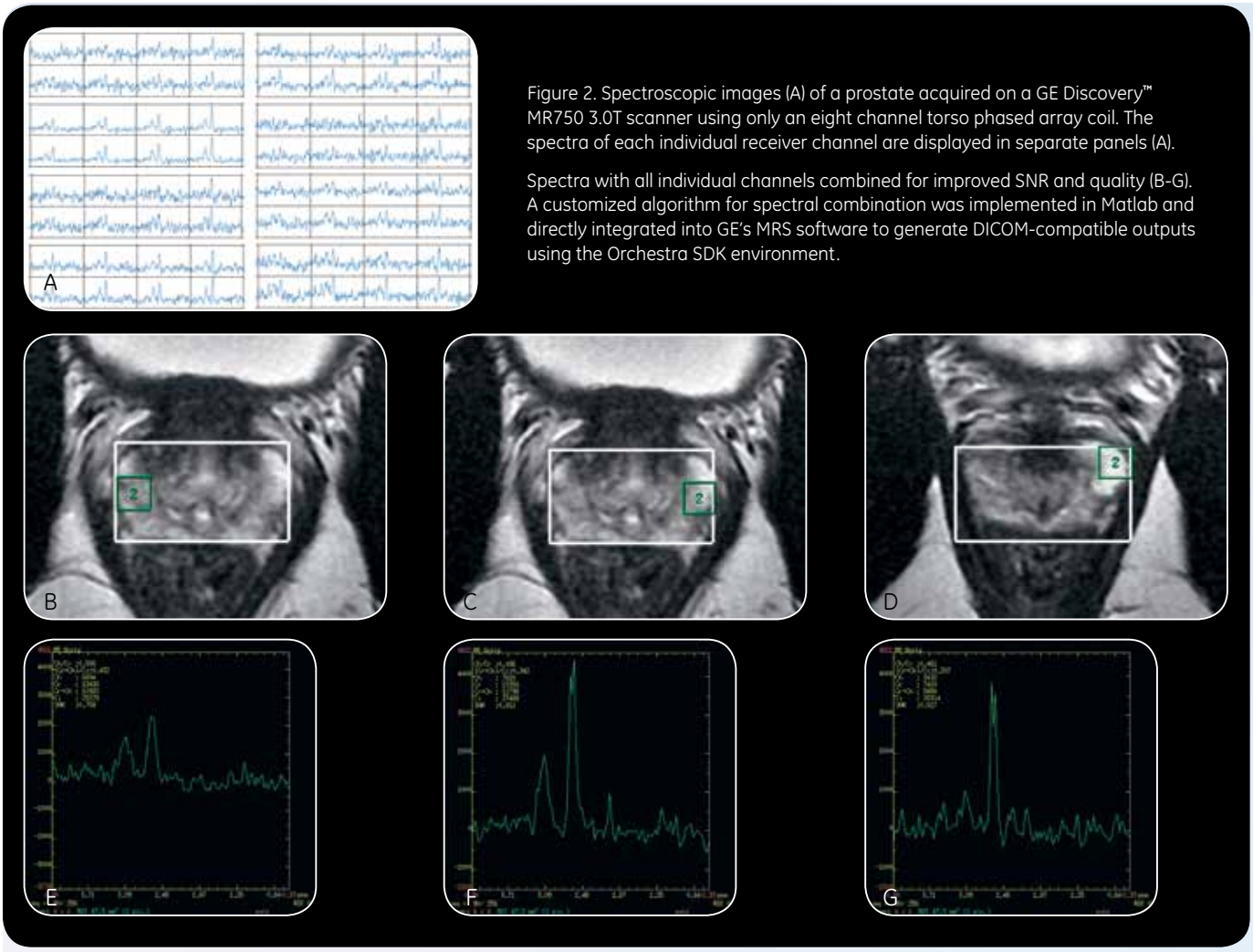


Figure 2. Spectroscopic images (A) of a prostate acquired on a GE Discovery™ MR750 3.0T scanner using only an eight channel torso phased array coil. The spectra of each individual receiver channel are displayed in separate panels (A).

Spectra with all individual channels combined for improved SNR and quality (B-G). A customized algorithm for spectral combination was implemented in Matlab and directly integrated into GE's MRS software to generate DICOM-compatible outputs using the Orchestra SDK environment.

MD Anderson Cancer Center

Jingfei Ma, PhD, Professor and Director of the MR Applications Laboratory, Department of Imaging Physics, Division of Diagnostic Imaging at The University of Texas MD Anderson Cancer Center in Houston, is also one of the first users of the new image reconstruction environment. He currently uses the Orchestra SDK for two projects in his lab: development of a 3.0T multi-channel prostate MR spectroscopic imaging technique (in collaboration with Haesun Choi, MD, Professor of Diagnostic Radiology, MD Anderson Cancer Center), and development of phase sensitive fast Dixon imaging techniques with a range of pulse sequences, such as extended LAVA Flex and extended fast triple echo Dixon. As a collaborator of the original LAVA Flex, he is well acquainted with the pulse sequence development using GE's EPIC environment, yet he finds Orchestra can help enhance his research capability because it puts many useful and GE-proprietary image reconstruction features at his fingertips. This allows him to implement and easily insert a customer reconstruction algorithm in the image reconstruction pipeline.

Before the Orchestra SDK, Dr. Ma says that even though he was able to save the raw data on a scanner, the overhead of just reading the raw data and putting the reconstructed images in a format presentable to a radiologist can be quite daunting. "In order to read the raw data, we had to learn the raw data file structure and modify our software codes every time there was a scanner upgrade. More importantly, we

Jingfei Ma, PhD,
is an ABR board-certified diagnostic radiological physicist at the MD Anderson Cancer Center in Houston, Texas.

did not have access to some essential GE image reconstruction features such as parallel imaging, GradWarp, and image rotation. As a result, it was difficult to directly compare a technique we tried to develop with an existing technique because the lack of parallel imaging often precludes a breath hold acquisition and the images from our reconstruction would appear distorted and mis-oriented without GradWarp and proper geometric rotation."

Dr. Ma continues, "Often, to develop a clinically useful technique, we work closely with radiologists on image quality assessment and the technique is optimized iteratively with their feedback. With the Orchestra SDK, the images we reconstructed using our algorithm can easily be installed back into the patient image database, with all the correct headers so a radiologist can read them and do comparisons just as if they were generated from a scanner. Orchestra saves us a lot of development time so I can focus on the details of our algorithm itself."

Dr. Ma further notes the importance of having access to features, such as GradWarp and parallel imaging. Firstly, implementing these features by a researcher outside GE would take a tremendous amount of resources. Also, since the features provided by Orchestra are identical to those used by a scanner. Image differences or improvement over an existing technique can be more confidently attributed to the core algorithm he tries to develop.

Increased flexibility is another advantage with the ability to perform reconstruction away from the MR scanner and to incorporate reconstruction code in both C++ and MATLAB. "It is important that we can do development work in different platforms or workstations and even send images into a PACS. It is a major advancement that I can now insert my MATLAB code, without having to convert it to C++, in a package that can read in MR raw data and generate completely DICOM-compatible images," comments Dr. Ma. He is also using the online collaboration portal. "It provides an efficient group discussion forum for different users and GE to exchange information and post questions. The response time has usually been very short and I find it to be quite useful for the work I am doing."

For the project developing a 3.0T multi-channel prostate MR spectroscopic imaging technique, Dr. Ma and his collaborators were able to leverage the Orchestra SDK and in a very short time, create a package that is being used in a clinical validation study. "The goal of our project was to investigate whether prostate spectroscopic imaging can be clinically performed using a multi-channel surface coil. We need to implement and evaluate different ways of combining spectroscopic images from the different receive channels. From the beginning, to providing a usable sequence with a spectrum that a radiologist can read, it took us only a few weeks rather than many months or even longer if it were not for Orchestra."

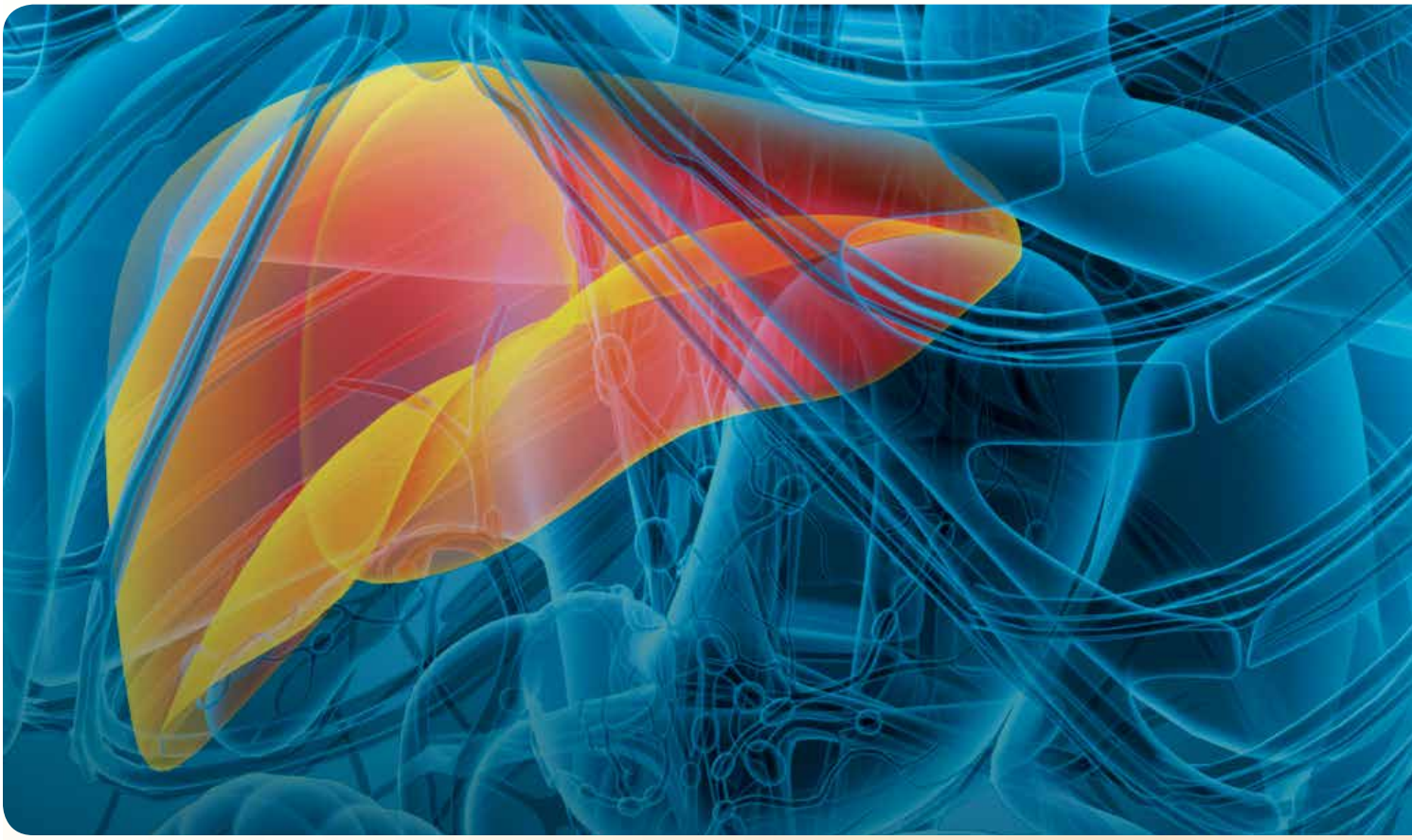
"The Orchestra SDK has definitely facilitated our development and collaboration with the radiologists. It also has potential to simplify and enhance collaborations across different institutions." Dr. Ma says, "This tool kit has been on a wish list of many MR researchers for a long time."

Kevin Koch, PhD, *is an Associate Professor in the Department of Biophysics and Radiology at the Medical College of Wisconsin in Milwaukee, WI. His main research interests are metal artifact reduction methods for MR and Quantitative Susceptibility Mapping in MR.*

The Medical College of Wisconsin *is a private, freestanding medical school and graduate school of sciences located in Milwaukee.*

Jingfei Ma, PhD, *is an ABR board-certified diagnostic radiological physicist at the MD Anderson Cancer Center in Houston, Texas. His main research interests are developing novel and clinically impactful MR pulse sequences and image reconstruction algorithms, as well as using MR for cancer characterization and therapy assessment.*

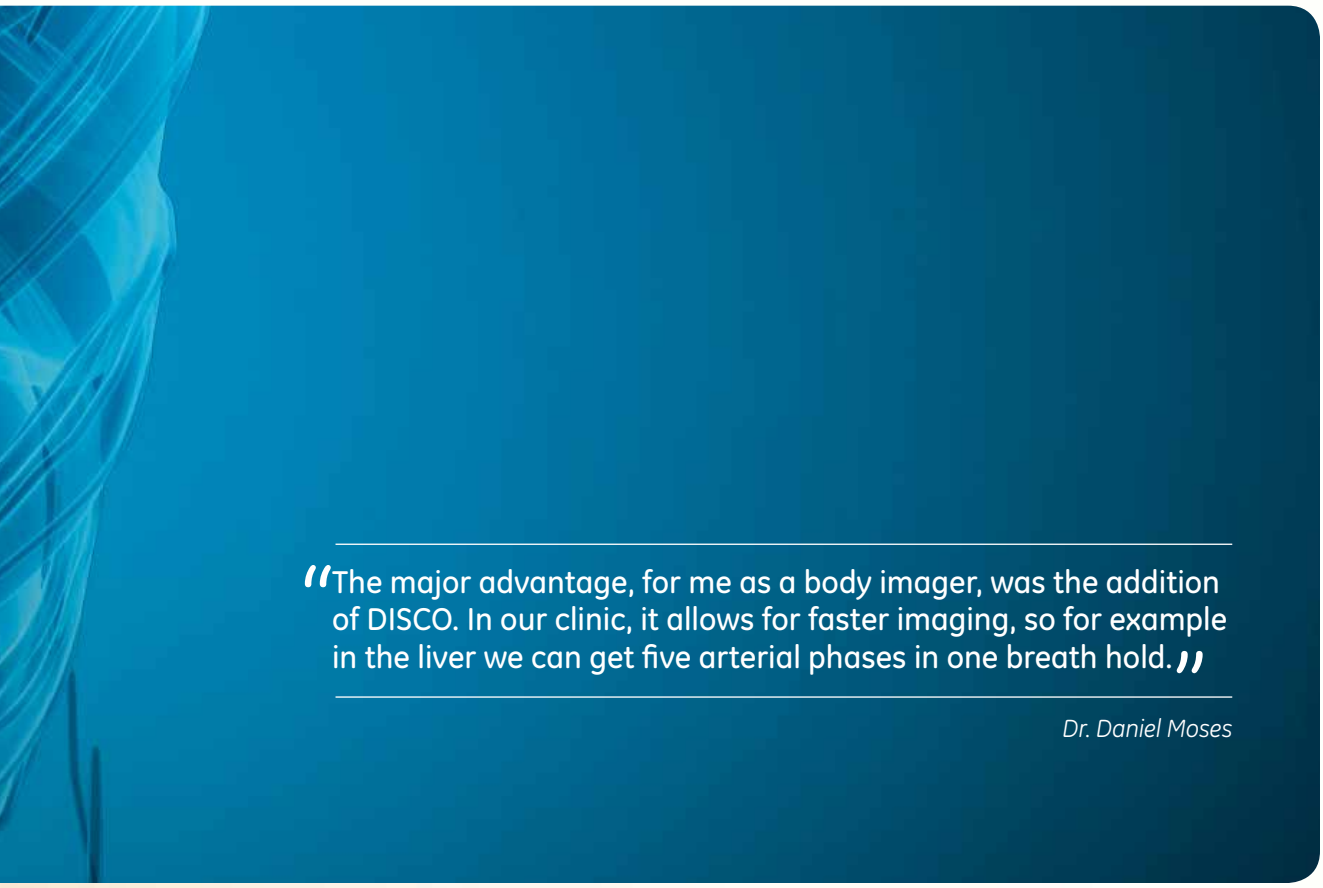
The University of Texas MD Anderson Cancer Center *in Houston is one of the original three comprehensive cancer centers in the United States established by the National Cancer Act of 1971.*



Spectrum Imaging Leverages DV25.0 Continuum Pak Applications

Wales Medical Centre

Spectrum Medical Imaging is an independent radiology practice providing state-of-the-art imaging services across Eastern and South Western Sydney, Australia since 2009. The practice has seven imaging centers, with two flagship sites—Liverpool and Randwick—both located near a main teaching hospital: Liverpool Public Hospital and Prince of Wales Public Hospital. At these two sites and one other, Spectrum offers MR imaging in addition to an array of other advanced imaging services.



> "The major advantage, for me as a body imager, was the addition of DISCO. In our clinic, it allows for faster imaging, so for example in the liver we can get five arterial phases in one breath hold."

Dr. Daniel Moses

The practice's first MR scanner was a SIGNA™ HDe 1.5T for the Liverpool site. "We were just starting our practice, so it was a very economical, well valued scanner that we could use for all the basic body, MSK, and neuro imaging," says Daniel Moses, MD, a radiologist at Spectrum. While the system performed well, Dr. Moses says the practice wanted to take MR imaging to the next level and have the capability to provide more advanced and complex imaging, particularly for the body. "A lot of high end body work is not done in the hospitals, so that gives practices like ours the opportunity to do that imaging in the clinics."

In 2013, Spectrum replaced the SIGNA HDe with an Optima™ MR450w and also acquired its first 3.0T MR, a Discovery™ MR750w. With these scanners, the practice was also able to expand into prostate MR imaging services.

"The 3.0T is what really helped us grow the prostate imaging service line," explains Dr. Moses. "We perform prostate exams on the 1.5T and it's very good, but the 3.0T takes the imaging to a new level and the image quality enables more confidence in our diagnosis."

Spectrum and GE Healthcare have developed a mutually collaborative relationship. This enabled Spectrum to be one of the first sites in the world to have access to and evaluate the DV25.0 Continuum™ Pak featuring an array of new and expanded sequences, including DISCO, SilentSuite, MAVRIC SL 2.0, Turbo LAVA, Cube DIR, and MDE Plus.

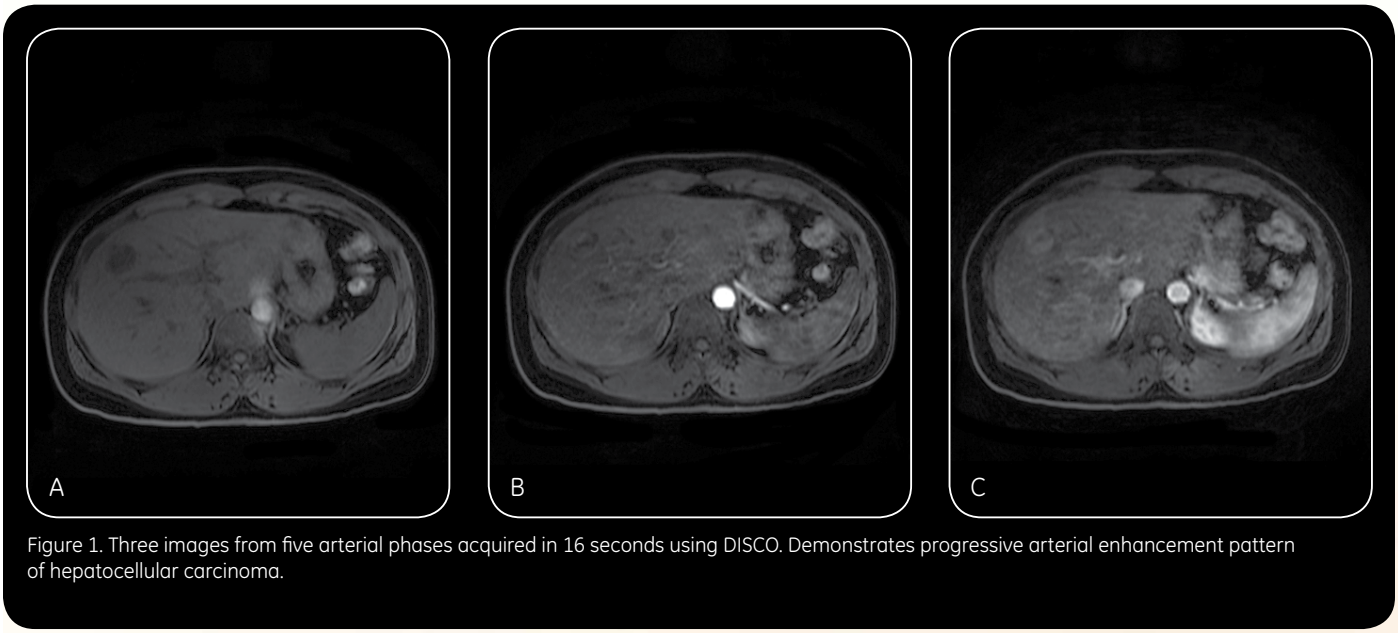


Figure 1. Three images from five arterial phases acquired in 16 seconds using DISCO. Demonstrates progressive arterial enhancement pattern of hepatocellular carcinoma.

Interest in body MR continues to increase from referring physicians, making it an important service line for Spectrum.

"The major advantage, for me as a body imager, was the addition of DISCO," says Dr. Moses. "In our clinic, it allows for faster imaging, so for example in the liver we can get five arterial phases in one breath hold." He explains that before DISCO (Differential Sub-sampling with Cartesian Ordering), there could be timing issues with capturing this phase correctly. It's a very important phase that would sometimes be missed. Now, he can see it and feel more confident that he probably hasn't missed anything (Figure 1 and 2).

"We also have LAVA Flex, and that is slightly faster than DISCO, so we can trade off fast imaging for good spatial resolution when needed," he adds.

DISCO uses a dual-echo 3D SPGR sequence with pseudo-random variable density k-space segmentation and a view sharing reconstruction to achieve high spatio-temporal resolution. DISCO samples an elliptically ordered central k-space region every temporal frame, and sub-samples the outer regions in a pseudo-random fashion rendering aliasing artifacts from sub-sampling incoherent.

It also can achieve robust fat suppression using a two-point Dixon fat-water reconstruction algorithm, which appears to be better suited than conventional fat suppression methods for combination with irregular k-space sampling schemes such as DISCO.

DISCO is also very useful for prostate imaging, where Dr. Moses has been able to get the temporal resolution as low as 3 seconds. While TRICKS can help reduce temporal resolution, it's really designed for examining the arteries, so it doesn't provide good contrast enhancement in the organs, Dr. Moses explains.

Daniel Moses, MD,
is a radiologist at Spectrum Medical Imaging in Sydney, Australia.

"(With DISCO) I believe there is a huge difference between 7 seconds and 3 seconds, and if something enhances early you can see it at 3 seconds. At 7 seconds it dilutes out over time, so there is an improvement."

Dr. Daniel Moses

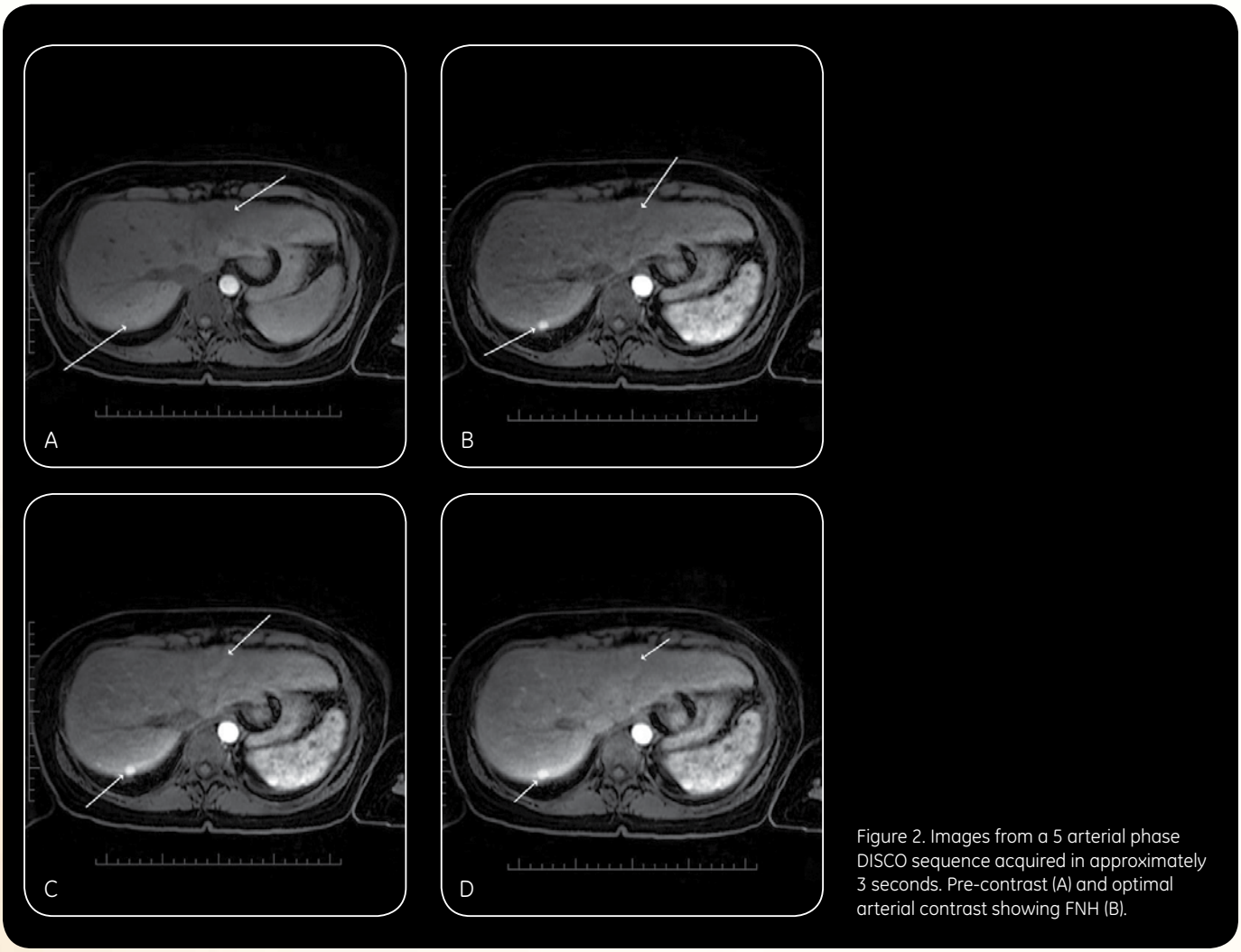


Figure 2. Images from a 5 arterial phase DISCO sequence acquired in approximately 3 seconds. Pre-contrast (A) and optimal arterial contrast showing FNH (B).

"When we used DISCO, we got the same temporal resolution and contrast resolution as TRICKS so it really did make a difference in seeing the enhancement," he says. "I believe there is a huge difference between 7 seconds and 3 seconds, and if something enhances early you can see it at 3 seconds. At 7 seconds it dilutes out over time, so there is an improvement."

Also, with the faster reconstruction time with the DV25.0 Continuum Pak, Dr. Moses says that if needed, he can review the images and determine if additional imaging is needed while the patient is still in the scanner. The reduced reconstruction time has also helped streamline workflow. "It makes us more efficient, so we can get through more cases, but we are also more confident with our reports. That helps us do a better job, which helps us grow our business."

According to Dr. Moses, Spectrum has experienced a significant increase in referrals for prostate MR imaging, particularly from urologists. They have gone from scanning approximately 10 patients each month to between 80 and 100.

In prostate imaging, Dr. Moses will also use PURE, a technique for enabling uniformity across the field even in areas of the body that are further from the coil. "It's nice to see a uniform image across the entire field of view; that helps us see odd things that we could otherwise miss."

FOCUS is also useful for imaging the prostate and rectum, Dr. Moses says. "The higher spatial resolution was quickly apparent and it has made a difference in terms of localizing features of the lesion." He was using FOCUS in parallel with a standard

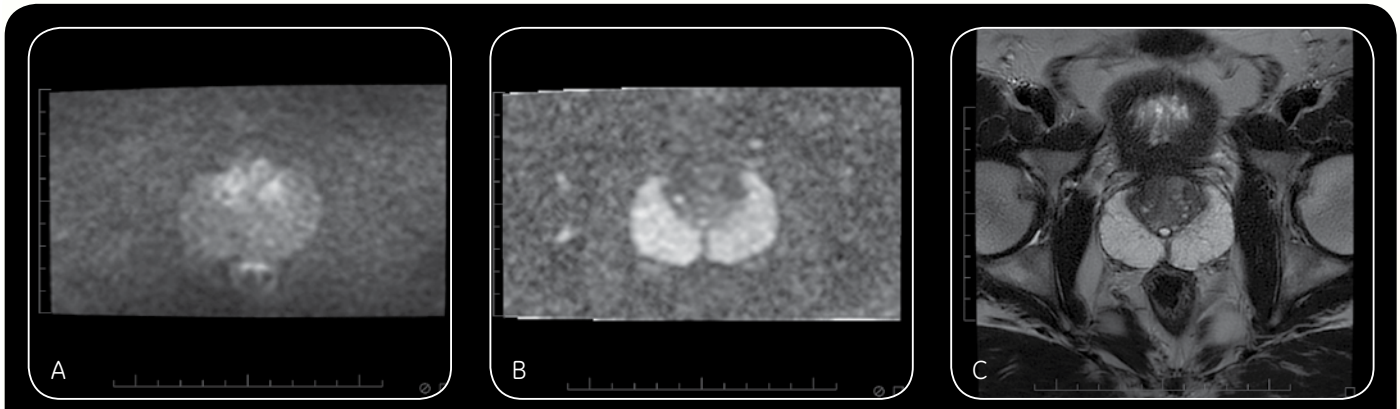


Figure 3. Images demonstrate excellent spatial and contrast resolution at 3.0T in the FOCUS diffusion weighted sequences (A), the ADC derived from FOCUS (B), and the T2w (C).

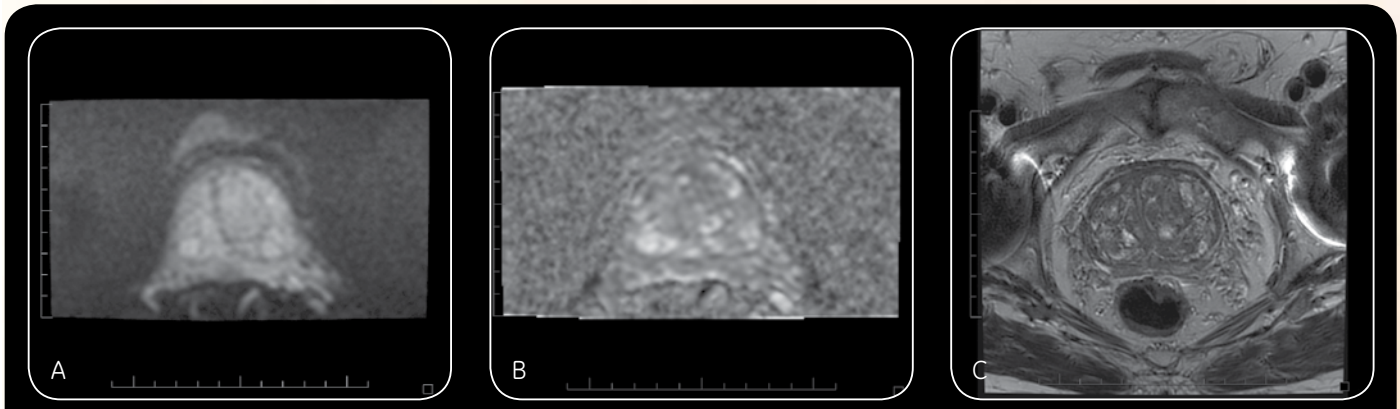


Figure 4. Patient with bi-lateral hip replacement. FOCUS DWI with the b-value (A); corresponding ADC map indicates hypo intense signal in the anterior part of the prostate (B); and T2 (C).

DWI sequence, but has now dropped the DWI as FOCUS provides him the information he needs to make a confident diagnosis.

Previously with DWI, he observed frequent failed scans due to severe geometric distortion at air-tissue interfaces around the prostate and rectum. In addition, many elderly prostate cancer patients have hip prosthesis. With FOCUS he is able to obtain diagnostic quality DWI images even in patients with bi-lateral hip replacement (Figure 4).

> "The higher spatial resolution (of FOCUS) was immediately apparent and it has made a difference in terms of localizing features of the lesion."
>
> *Dr. Daniel Moses*

The practice is also ramping up use of SilentScan, especially for pediatrics. In the DV25.0 Continuum Pak, SilentScan can be used with T1, T2, MRA, and DWI sequences.

Having these imaging advantages is important for our practice, Dr. Moses says, but it's even more important for our patients. "A good percentage of patients will benefit in liver follow-up studies with our use of DISCO," he says. "In radiology, having these advancements along with some of the best technology available is just good for both our clinicians and our patients."

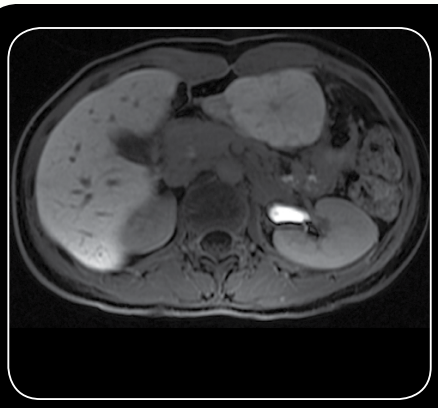


Figure 5. Large FNH depicted with LAVA Flex on a 20 min delayed gadoxetate disodium injection (hepatocellular) phase.

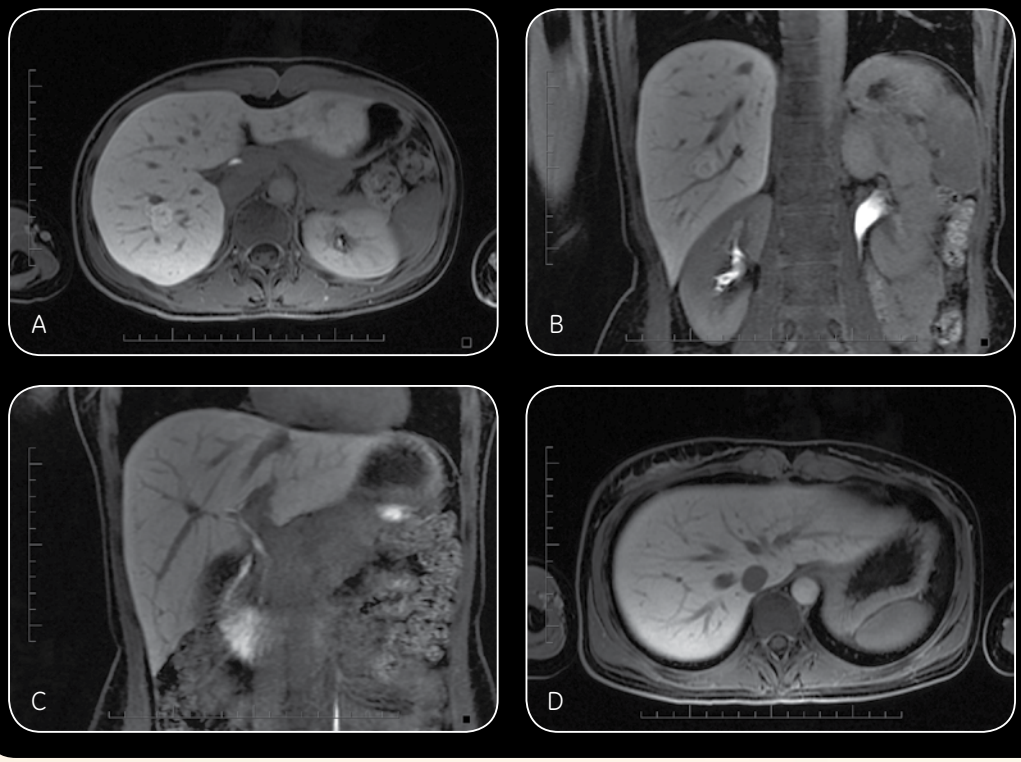


Figure 6. Liver imaging demonstrating an FNH.

Daniel Moses, MD, *is a radiologist at Spectrum Medical Imaging and currently is the Director of Medical Imaging of the Northern Network of Hospitals, SESIAHS, and holds a senior staff specialist position with a subspecialty in body, thoracic, and cardiac radiology. Dr Moses graduated from the University of New South Wales with a combined degree in Science (Mathematics/Physics) and Medicine. He completed his training in radiology at Prince of Wales Hospital and was awarded the Thomas Baker Fellowship from the RANZCR to travel to New York, where he obtained fellowships in Thoracic Radiology and Body MRI from New York University. He has a strong interest in body MR/CT with extensive experience in chest, abdominal and urological imaging (including intervention). He is a fellow of the RANZCR and accredited by the American Board of Radiology and the specialist register in the UK.*

Spectrum Medical Imaging *is an independent radiology practice with no corporate affiliations, owned and operated by hospital radiologists based at Liverpool Public Hospital and Prince of Wales Public Hospital. Spectrum offers comprehensive state-of-the-art imaging services at seven sites, including X-Ray, Ultrasound, CT, MRI, DEXA/BMD, Interventional – Biopsies & Injections, Women's Imaging, Paediatric Imaging, Sports Imaging and Dental Imaging.*

DV25.0 Continuum Pak Upgrade Helps Facility Reduce Breath Hold Times and Optimize Exams

St. Joseph's Healthcare Hamilton (SJHH) in Ontario, Canada is a premier academic and research healthcare organization. Its diagnostic imaging department houses a state-of-the-art imaging facility where more than 200,000 procedures and examinations are performed annually. The MR studies, which are done on an Optima™ MR450w with GEM from GE Healthcare, include angiography, body, brain, cardiac, head, MSK, and spine.

According to Ryan Rebello, MD, Director of MRI and a radiologist at SJHH, the outpatient department scans around 40 abdomen, pelvis, and vascular cases each week. "We are one of the biggest providers of MR enterography in southwest Ontario performing more than 20 cases each week. Additionally, as a tertiary care nephrology and urology center, we perform a high volume of renal MR."

Janet Burr, Senior MRI Technologist at SJHH, says that because of the facility's patient population with multiple co-morbidities, breath holding is often an issue. "Anything that can increase speed of the acquisition post-contrast is a big benefit for us."

Leading MR advancements

SJHH recently upgraded to GE's new DV25.0 Continuum™ Pak, which provides the facility with leading MR advancements while expanding commitment to patient care. The facility's clinicians are currently utilizing Turbo LAVA, which provides up to 40% reduced breath hold times compared to conventional techniques, and DISCO (Differential Sub-sampling with Cartesian Ordering), which uses a dual-echo 3D SPGR sequence with pseudo-random variable density k-space segmentation and a view-sharing reconstruction to achieve high spatio-temporal resolution.

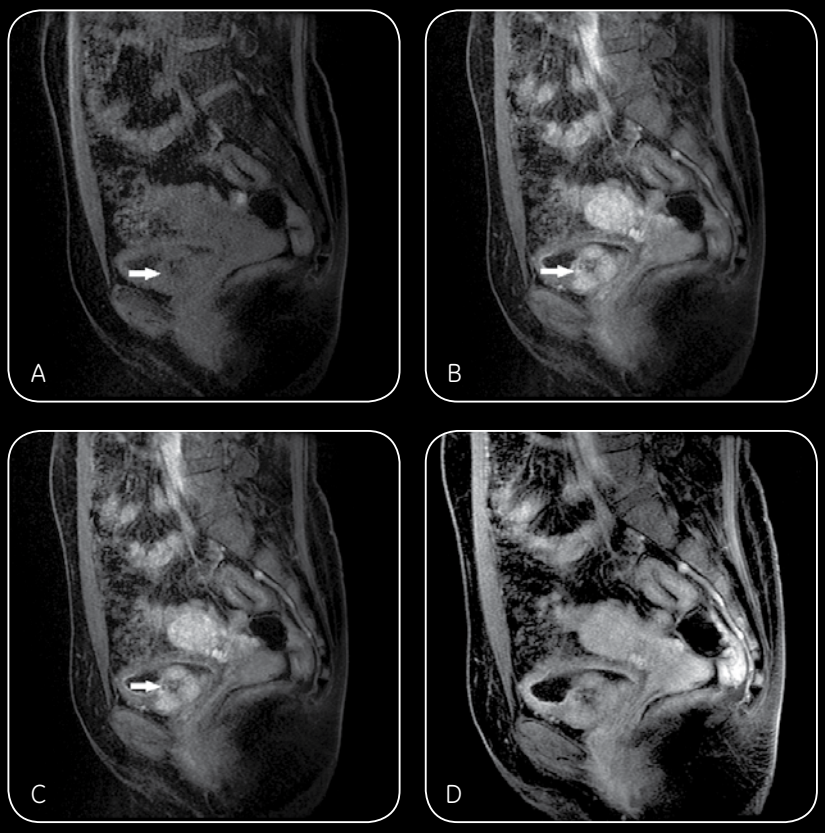


Figure 1. Female pelvis on a patient with Ewing sarcoma of the bladder. DISCO LAVA Flex water images showing pre- and post-contrast arrival (A, B, and C). Temporal resolution for this exam was 5 seconds per phase. Turbo LAVA Flex post contrast images (D).

DISCO parameters
320 x 224
4.4mm slice thickness
5 seconds per phase
5 phases

Turbo LAVA parameters
320 x 192
4mm slice thickness
20 seconds

"For body imaging, we can use Turbo LAVA Flex pre- and post-contrast, and the images are of very good quality. Included in this 3D acquisition we get in- and out-of-phase information, resulting in time savings," says Burr. "The breath hold times can be decreased, so if a patient can not hold their breath very well, we can manipulate that time and still obtain excellent quality images."

For example Dr. Rebello explains, "With Turbo LAVA, a breath hold for liver or kidneys is now around 14 seconds... that's 4 or 5 seconds shorter than before, which can make a world of difference in some of our patients. Plus, a lower percentage of post-Gadolinium sequences are affected by motion artifact. By minimizing motion artifacts, we get a better percentage of usable diagnostic scans for more confidence in our reports."

Burr continues that thought, "While it's difficult to get images from a certain percentage of our patient population, Turbo LAVA provides us with diagnostic sequences giving us more confidence in our reports. On the other hand, if we have an optimal patient, we get beautiful images. Plus, the sequences are done quickly, as we are always balancing efficiency versus quality."

Furthermore, SJHH is very pleased with DISCO. "When we received DISCO we implemented it into as many different protocols as possible. Wherever we would have done a multi-phase post-contrast sequence, we replaced the arterial phase with the new application. It is an opportunity for us to capture temporal information in addition to anatomic detail," offers Burr.

Every MR center is challenged with the need for efficiency while maintaining quality, according to Burr. "DV25.0 Continuum Pak has helped us scan in a very efficient way with reproducible image quality produced by multiple technologists."

Dr. Rebello concurs. "Having a more powerful reconstruction engine, provided by DISCO and the upgrade to DV25.0, has been an extra benefit for us and our patients. In most of our vascular protocols we use time-resolved MRA or TRICKS, and now the computer reconstruction time is very fast, in terms of being able to review the imaging and target any post-contrast imaging, to what appears on the MR angiogram."

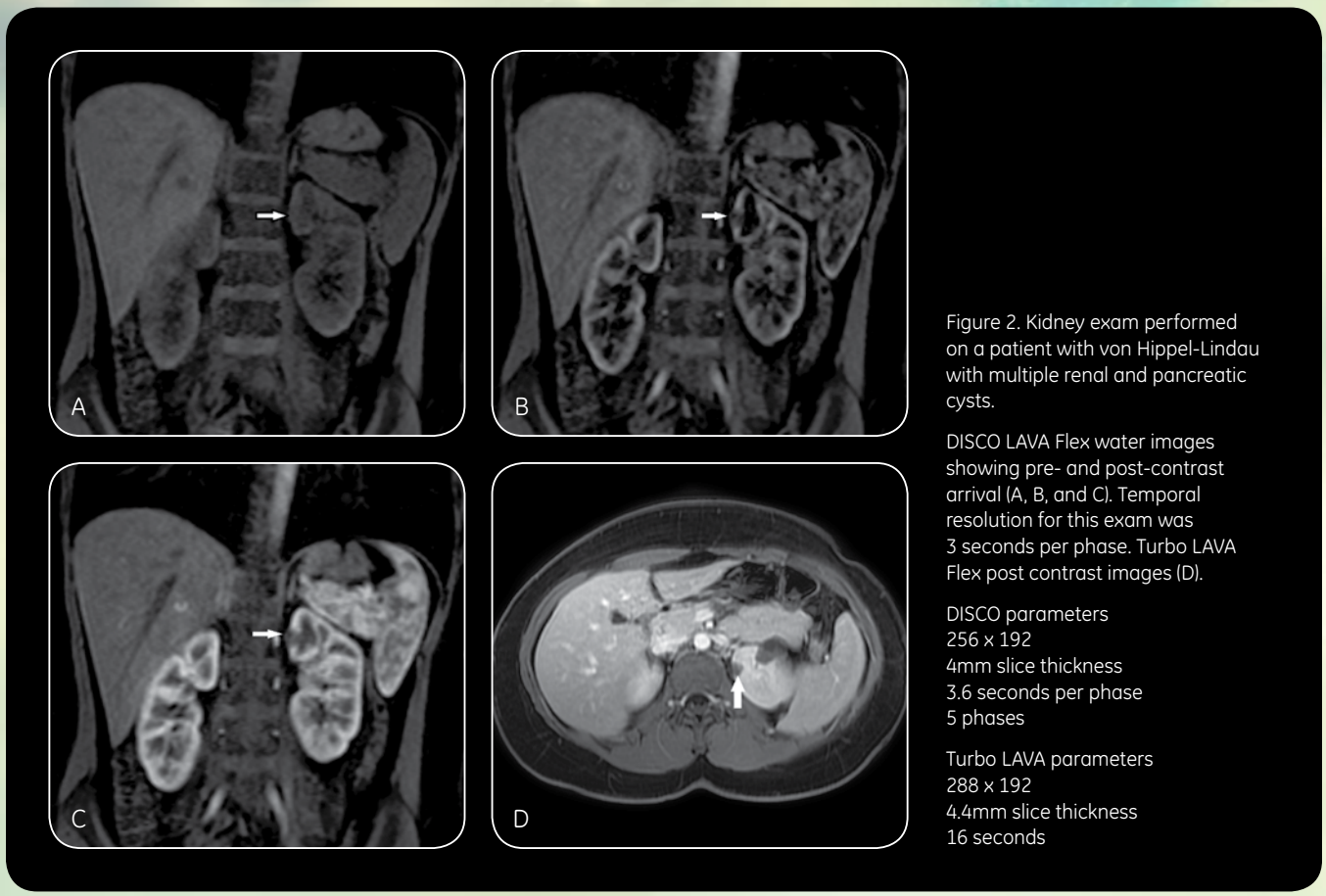


Figure 2. Kidney exam performed on a patient with von Hippel-Lindau with multiple renal and pancreatic cysts.

DISCO LAVA Flex water images showing pre- and post-contrast arrival (A, B, and C). Temporal resolution for this exam was 3 seconds per phase. Turbo LAVA Flex post contrast images (D).

DISCO parameters
256 x 192
4mm slice thickness
3.6 seconds per phase
5 phases

Turbo LAVA parameters
288 x 192
4.4mm slice thickness
16 seconds

More information, flexibility

"With the upgrade, there are so many factors that we can change—spatial resolution, temporal resolution, number of phases," states Dr. Rebello. "We do most of our DISCO exams with between 5 and 8 phases and we typically aim for arterial phase imaging. By doing so, we get more perfusion information; for example, when assessing disease activity in Crohn's patients with MR enterography. This type of information offers us insight into physiology and pathology in addition to a good amount of anatomic detail."

Dr. Rebello says that with hypervascular lesions in the liver, such as hepatocellular carcinoma (HCC) or neuroendocrine metastases, if the arterial phase timing is off or blurred by motion artifact, the diagnosis can be missed or uncertain. "But the DISCO upgrade gives us extra scope to catch arterial enhancement and helps us more definitively characterize something as HCC—if we have multiple 4-5 second passes as opposed to one longer arterial phase."

Burr states, "Considering our patient population, a failed breath hold during the arterial phase could be considered a non-diagnostic exam. If patients can only hold their breath for 4 or 5 seconds, we might end up with a successful exam if we have at least some information in one of the arterial phases."

Dr. Rebello concurs. "We have a better chance of getting a diagnostic set of images with one of those 4 second phases with DISCO versus 14 to 18 seconds with LAVA or Turbo LAVA. It gives us more flexibility."

Ryan Rebello, MD,
is the Director of MRI and a radiologist at St. Joseph's Healthcare Hamilton in Ontario, Canada.

Janet Burr,
is a Senior MRI Technologist at St. Joseph's Healthcare Hamilton in Ontario, Canada.

> "(DV25.0) allows us to get physiological information and reasonable spatial resolution in a short breath hold. Furthermore, it provides us with a better image in order for assessment of disease activity, neo-angiogenesis, and response to therapy in a wide array of conditions. DV25.0 affords us a variety of imaging options and flexibility that can be tailored to suit an expanding and diversifying MR patient population."
>
> *Dr. Ryan Rebello*

"Over the last several years, SJHH's MR exams have shifted to higher acuity requests," according to Burr. Dr. Rebello states that the upgrade "allows us to scan patients that previously we would not have considered for MR due to long exam times and lengthy breath holds. Previously, we may have used an alternative modality such as CT."

In conclusion, Burr notes, "DV25.0 has given us increased confidence, reproducibility, and speed."

Dr. Rebello comments, "It allows us to get physiological information and reasonable spatial resolution in a short breath hold. Furthermore, it provides us with a better image in order for assessment of disease activity, neo-angiogenesis, and response to therapy in a wide array of conditions. DV25.0 affords us a variety of imaging options and flexibility that can be tailored to suit an expanding and diversifying MR patient population."

Ryan Rebello, MD, *is the Director of MRI and a radiologist at St. Joseph's Healthcare Hamilton in Ontario, Canada. He has been a radiologist at SJHH for 11 years, with an interest in body, vascular, and neuro imaging.*

Janet Burr, *is a Senior MRI Technologist at St. Joseph's Healthcare Hamilton in Ontario, Canada. She has been a technologist for 23 years with almost 20 years of MRI experience.*

St. Joseph's Healthcare Hamilton (SJHH) *in Ontario, Canada is a premier academic and research healthcare organization. Its diagnostic imaging department houses a state-of-the-art imaging facility where more than 200,000 procedures and examinations are performed annually.*

High-resolution Breast Imaging with DV25.0 Continuum Pak and DISCO

By Francois D'Anthouard, MD, Radiologist, GIE IRM Creil, France

Optima™ MR450w with GEM

DIGITAL DIVE
For parameters go to tiny.cc/sps151

Introduction

Dynamic contrast-enhanced MR (DCE MR) is commonly used for detection and characterization of malignancies in the breast. However, suboptimal compromises are often made between temporal and spatial resolution in conventional breast DCE MR[1]. A high spatial resolution is required to characterize lesion morphology, whereas a high temporal resolution is required to accurately characterize contrast uptake both for semi-quantitative and quantitative analysis of contrast enhancement kinetics.

Conventional clinical breast DCE MR often falls into either high spatial (low temporal) resolution or high temporal (low spatial) resolution regimes,[1,2] although high spatial resolution imaging is increasingly being used. The American College of Radiology guidelines recommend 1mm in-plane spatial resolution, slice thickness of 3mm or less, and enhancement data acquired at intervals spaced 120 sec or less.

MR technique

Figure 1 depicts the DISCO-DCE acquisition scheme and the k-space segmentation used in our breast DCE MR acquisitions. The innermost region A is fully sampled while the middle annulus B is undersampled trifold as B1, B2, and B3. The relative fractional sizes of A and B1 are 0.3 and (1–0.3)/3 = 0.23 respectively.

Figure 2 depicts the data acquisition pattern to obtain the subsequent phases of the DISCO acquisition: A high spatial resolution pre-contrast acquisition was acquired covering the entire k-space (includes all regions).

Following injection of contrast media, dynamic images with short temporal resolution were acquired over a period of several minutes, where only a part of k-space (B region) was acquired for each dynamic phase. Each phase was then

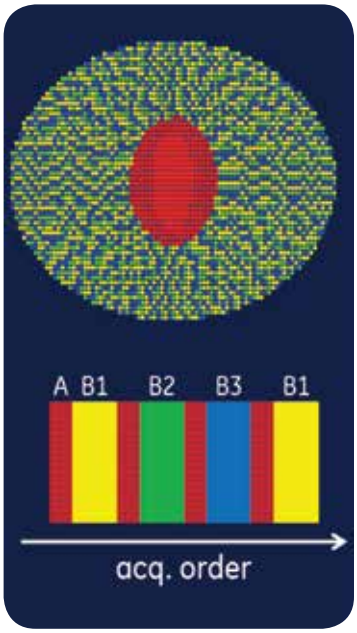


Figure 1. Depicts the DISCO-DCE acquisition scheme.

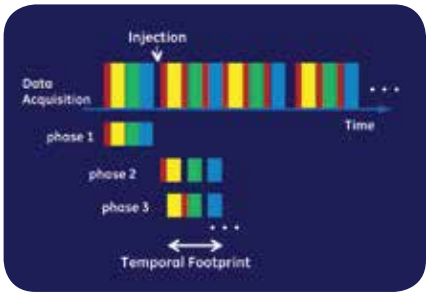


Figure 2. Depicts the data acquisition pattern.

Francois D'Anthouard, MD,
is a radiologist at GIE IRM Creil in Creil, France.

reconstructed from a single center of a k-space (A) combined with the nearest peripheral k-space neighbors (B1+B2+B3).

With the introduction of the release of GE Healthcare's DV25.0 Continuum™ Pak, we were able to use a new variable spatiotemporal resolution dynamic contrast-enhanced (DCE) MR method, termed DIfferential Subsampling with Cartesian Ordering (DISCO), for imaging of breast cancer.[2] This sequence combines a dual-echo SPGR sequence with Dixon fat–water separation, pseudorandom variable density, and k-space segmentation, to provide high resolution combined with high temporal resolution. DISCO is also available in a single echo mode with SSRF water excitation to provide T1w "fat suppressed" images.

With this technique, we were able to achieve an in-plane spatial resolution of 0.82mm and slice thickness of 1.2mm (0.6mm with Zip2 option) while keeping the temporal resolution as low as 63 sec per phase for the dual echo mode, and 84 sec per phase for the single echo mode.

Case 1

An elderly patient was referred for an MR exam of a left breast lesion after mammography and ultrasound. The lesion appeared to be markedly hypoechoic on the ultrasound exam. The MR exam protocol was axial T2w PROPELLER, axial DCE imaging with DISCO Flex, and axial late phase with DISCO Single Echo FatSat.

Findings

The DISCO sequence improved spatial resolution compared to standard DCE imaging. The DISCO Flex or Single Echo options provided tailored CNR.

Discussion

We noticed a 9mm spiculated lesion in the infero external quadrant of the left breast, corresponding to the lesion seen at mammography and ultrasound. Suspicion of a high grade ductal carcinoma. We also noticed two additional small lesions, located in the upper breast, at the junction of external quadrants. Ultrasound-guided biopsy confirmed three locations of invasive ductal carcinoma.

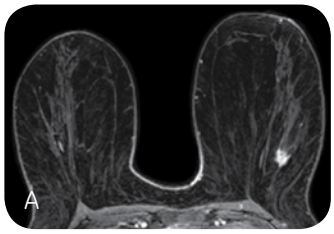


Figure 3A. DISCO Flex 512 x 512
1.2mm/-0.5mm 66 sec phase
Lesion #1

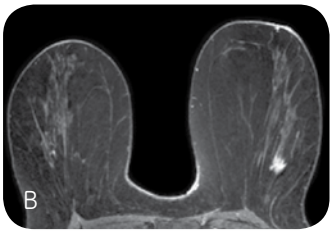


Figure 3B. DISCO Single Echo
512 x 512
1.2mm/-0.5mm 84 sec phase
Lesion #1

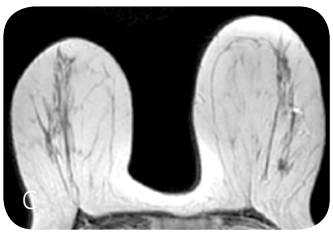


Figure 3C. T2w PROPELLER
352 x 352
2mm – 4:07 min

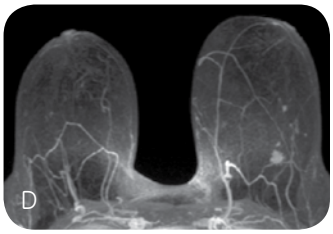


Figure 3D. 3D MIP of DISCO
Single Echo

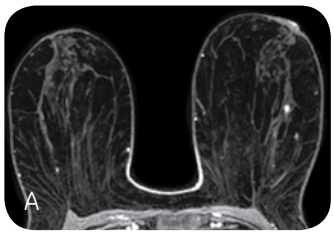


Figure 4A. DISCO Flex 512 x 512
1.2mm/-0.5mm 66 sec phase
Lesion #2

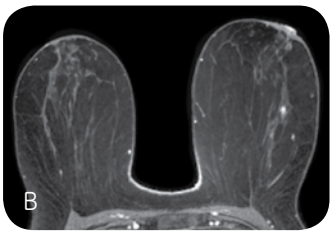


Figure 4B. DISCO Single Echo
512 x 512
1.2mm/-0.5mm 84 sec phase
Lesion #2

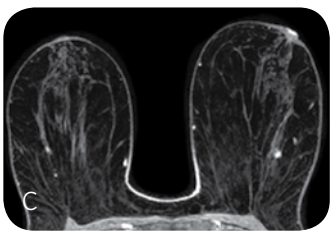


Figure 4C. DISCO Flex 512 x 512
1.2mm/-0.5mm 66 sec phase
Lesion #3

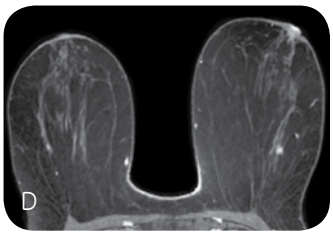


Figure 4D. DISCO Single Echo
512 x 512
1.2mm/-0.5mm 84 sec phase
Lesion #3

Case 2

A female patient was temporarily classified as BI-RADS™ category ACR 0 from a follow-up ultrasound and mammogram, performed one month before the MR exam, because of a small (4.7mm) opacity well circumscribed within very regular borders—located 3mm below a clip placed four years earlier during stereotactic macrobiopsy that confirmed dystrophy.

Findings

Dynamic 3D DISCO, 512^2 matrix, 1.2mm slice thickness, four phases every 90 seconds. Exam is interpreted by reviewing the native images with and without subtraction, and analyzing the contrast (Gd) uptake curves on AW. Left breast: clip is visible on the MR images due to the susceptibility signal void it generates. A micro nodular contrast enhancement, 3mm below the clip, corresponds to the ultrasound image. Borders are well delimited, with a round anterior portion and a rectilinear posterior portion. On the sagittal views, the anterior borders of the lesion are slightly less regular. No other enhancement on the left breast. Right breast: no focal enhancement and no detectable anomaly in the axillary region.

Discussion

Focal contrast enhancement right below the clip is in agreement with the ultrasound image that motivated the MR exam. Ultrasound-guided biopsy confirms invasive ductal carcinoma.

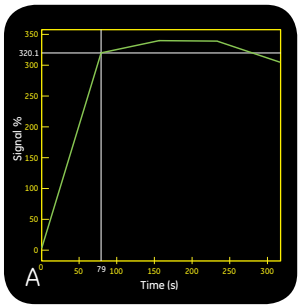


Figure 5A. Contrast uptake of the lesion in percentage of signal intensity.

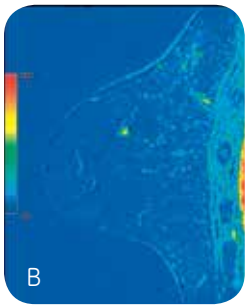


Figure 5B. Color map of the maximum slope of signal increase.

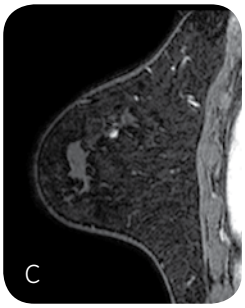


Figure 5C. DISCO water, sagittal reformat at maximum uptake time (79 sec).

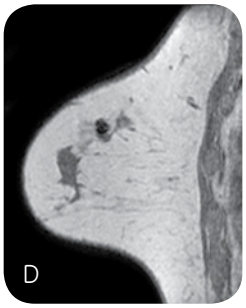


Figure 5D. DISCO in-phase, sagittal reformat, initial phase.

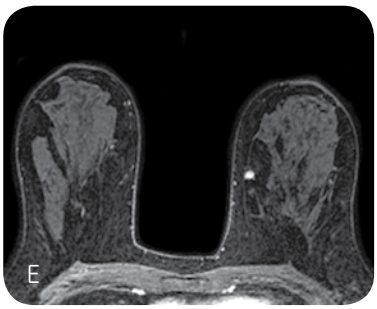


Figure 5E. DISCO water, native axial at maximum uptake time (79 sec).

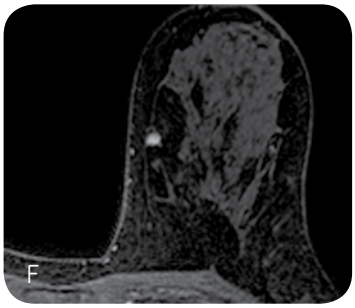


Figure 5F. Close up of left breast.

References

1. Kuhl CK, Schild HH, Morakkabati N. Dynamic bilateral contrast enhanced MR imaging of the breast: trade-off between spatial and temporal resolution. Radiology 2005; 236:789–800.
2. Saranathan M, Rettmann DW, Hargreaves BA, Clarke SE, Vasanawala SS. DIfferential subsampling with cartesian ordering (DISCO): a high spatio-temporal resolution Dixon imaging sequence for multiphasic contrast enhanced abdominal imaging. J Magn Reson Imaging 2012; 35:1484–1492.

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GIE IRM *in Creil, France specializes in MR, ultrasound, X-ray, CT, mammography, and bone densitometry.*

SIGNA™ PET/MR

Simultaneous Imaging of Ga-68 DOTA-TOC in Patients with Neuroendocrine Tumors

By Thomas A. Hope, MD, Assistant Professor in Residence, Sections of Abdominal Imaging and Nuclear Medicine, University of California, San Francisco (UCSF)

Somatostatin imaging has long been used for the detection of neuroendocrine cancer. Typically patients undergo SPECT/CT using In-111 labeled Octreotide. This approach may have several limitations including the requirement of a multiday exam, decreased sensitivity of SPECT, and potentially increased dose to the patient. Additionally, cross section imaging of the liver is nearly universally acquired in addition to the SPECT/CT, either using MR or CT. Newer agents have been developed that have faster uptake times and can be labeled with a PET emitter (Ga-68), allowing one to image the same patient using PET/CT performed one hour after injection.

The simultaneous modality, PET/MR, allows one to acquire the PET data from the injected Ga-68 DOTA-TOC‡, while at the same time acquiring liver images using hepatobiliary agents.

Patient history

A patient in their early 60s with a newly diagnosed, well-differentiated neuroendocrine tumor with hepatic metastasis. The diagnosis was made based upon a liver biopsy and the primary site remained unknown. The patient's carcinoid syndrome was resolved after the initiation of treatment over several weeks. A DOTA-TOC PET was ordered in order to assist the clinician in their evaluation of the extent of liver disease for surgical planning as well as for detection of the primary site of disease. The study was performed on a 3.0T time-of-flight SIGNA PET/MR.

Parameters	
PET	
Dose:	5.6 mCi
Uptake time:	2:15
Beds:	Six beds for whole body, single bed for liver
Total imaging time:	58 minutes
MR	
Hepatobiliary phase LAVA:	Spectral fat saturation; Navigated free breathing using diaphragm navigator
Matrix:	320 x 224
Slice thickness:	3.4mm
TE/TR:	2.04/5.59
Flip angle:	35 degrees

‡UCSF is currently studying the potential use of Ga-68 DOTA-TOC tracer in the evaluation of certain neuroendocrine disorders. Ga-68 DOTA-TOC is not FDA approved and is being utilized in this study under an IND.

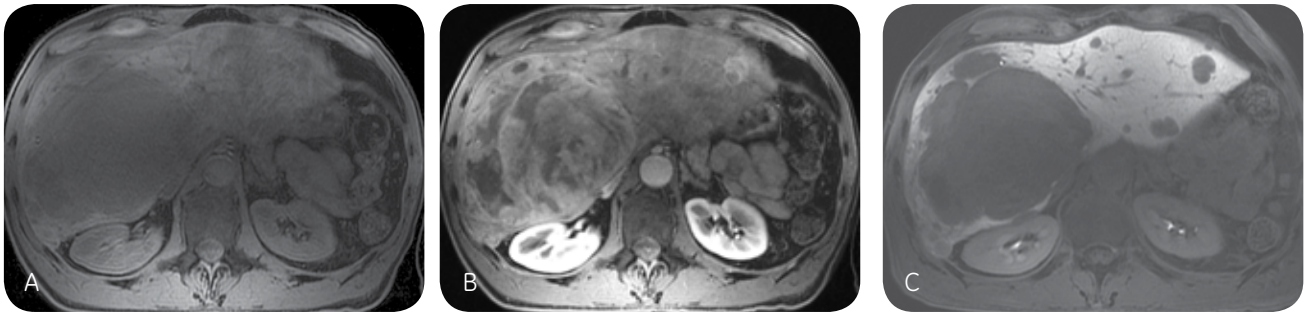

Figure 1. Pre-contrast (A), arterial phase (B), and hepatobiliary phase (C) of liver metastases using LAVA.

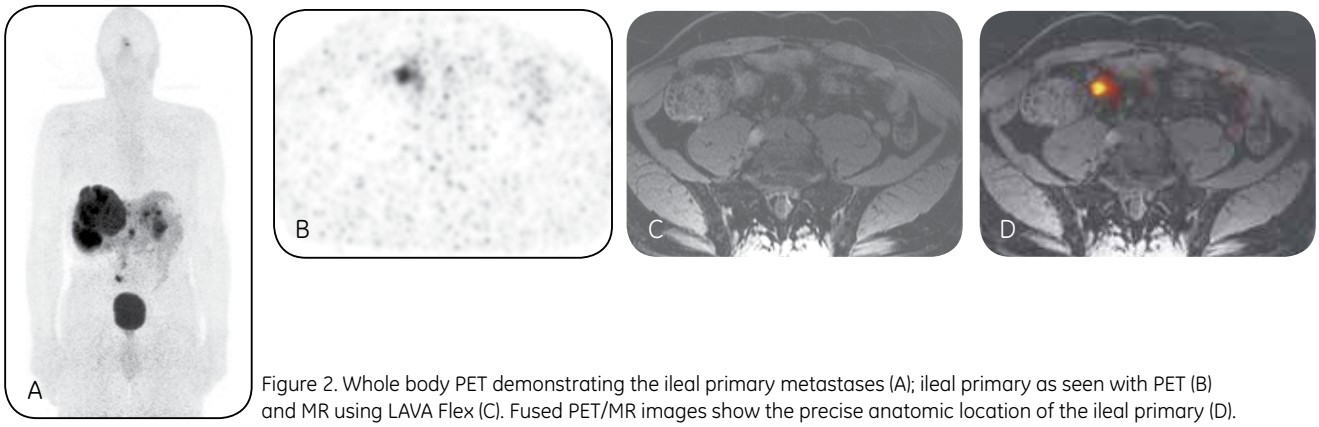

Figure 2. Whole body PET demonstrating the ileal primary metastases (A); ileal primary as seen with PET (B) and MR using LAVA Flex (C). Fused PET/MR images show the precise anatomic location of the ileal primary (D).

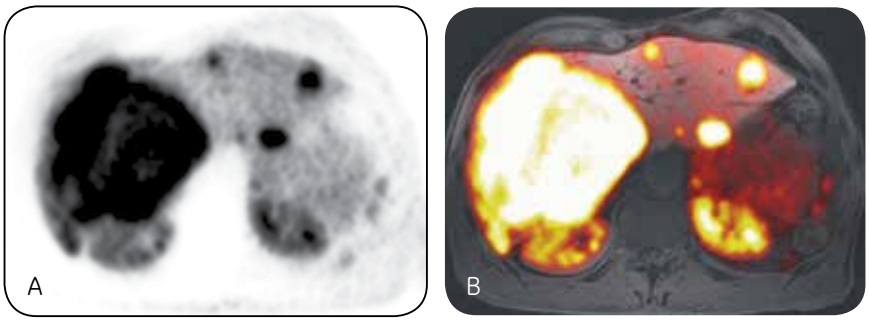

Figure 3. DOTA-TOC PET/MR demonstrated innumerable somatostatin receptor positive masses in the liver consistent with known hepatic metastasis.

Findings

DOTA-TOC PET/MR visualized innumerable somatostatin receptor positive masses in the liver consistent with known hepatic metastasis. The navigated axial LAVA hepatobiliary phase images accurately delineate the tumor margins with a high sensitivity. Additionally, the PET/MR imaged focal uptake in the terminal ileum, which was not seen on a prior CT of the abdomen and pelvis. Also, multiple avid nodules were noted by the clinician in the mesenteric root as well as along the splenic flexure. The patient is planned to undergo debulking surgery to remove the primary tumor as well as decrease the liver tumor burden.

Discussion

The simultaneous modality PET/MR is a great complement to imaging patients with neuroendocrine tumor. Previously, patients underwent a multiday OctreoScan SPECT study and additionally had multiple liver specific imaging studies. With simultaneous PET/MR imaging, patients can undergo a single study performed in less than one hour using less radiation dose than is associated with an OctreoScan.

Additionally, the high-resolution navigated hepatobiliary phase imaging provides the clinician with information to accurately delineate tumor margins and helps them in treatment planning for surgical resection. In the liver, the navigated imaging is acquired during normal shallow respiration and therefore fuses more accurately to the acquired PET data than conventional breath hold MRI.

We are just beginning to uncover the complementary benefit of combined MR and PET imaging, and as more agents in addition to FDG become approved for clinical use, PET/MR will provide additional diagnostic yield to studies and improve patient convenience.

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Imaging the Female Pelvis with FOCUS DWI and MR Spectroscopy

By Mayumi Takeuchi, MD, PhD, Associate Professor, Tokushima University Hospital, Japan

Discovery™ MR750 3.0T

To assist the clinician in their ability to diagnose female pelvic tumors, MR is frequently used as an imaging tool at Tokushima University, second only to ultrasound. It is a helpful tool in supporting the clinician to differentiate and localize tumors, assessing treatment effects, detecting recurrence, and distinguishing between benign tumors, such as myoma or adenomyosis of the uterus.

Tokushima University has a 3.0T (Discovery™ MR750) and two 1.5T (Signa™ HDxt 1.5T Optima™ Edition) MR systems. In general, we utilize all three systems for pelvis examinations. However, we now prefer the Discovery MR750 to evaluate lesions with the addition of FOCUS DWI or for cases where MR spectroscopy can help the clinician in providing a differential diagnosis.

Parameters	
Device:	Discovery MR750 3.0T
FOV:	14 x 5.6cm - 24 x 12cm
Matrix:	160 x 80
Slice thickness:	5-6mm
B value (s/mm^2):	800 s/mm^2
TR:	4,000 ms
TE:	55.3-58.9 ms
NEX:	10

Parameters for Case 1 and Case 2

High spatial resolution DWI with FOCUS in the female pelvis

DWI is a helpful tool to assist the clinician in their ability to characterize the aggressiveness of malignant tumors. The high-contrast resolution of DWI may improve the clinicians' ability to detect tumors, however, its low spatial resolution and increased susceptibility artifacts may limit its role for the clinician to evaluate tumor extent. FOCUS provides high-resolution DWI for a small field of view with significant reduction of susceptibility-induced distortion and loss of signal intensity.

Discussion

FOCUS DWI may be helpful in preoperative imaging of uterine endometrial cancer. For example, in this case it helped to depict the depth of myometrial invasion.[1] FOCUS DWI may also assist the clinician in their ability to accurately determine uterine cervical cancer by allowing better visualization of tumor size and parametrial tumor spread. In this case, when evaluating ovarian tumors, FOCUS DWI provided the clinician with anatomical detail such as intratumoral structures and high signal intensity solid malignant components within the mass.[2]

References

1. Takeuchi M et al. Diffusion-weighted magnetic resonance imaging of endometrial cancer: differentiation from benign endometrial lesions and preoperative assessment of myometrial invasion. Acta Radiol. 2009;50(8):947-53.

2. Takeuchi M et al. Diffusion-weighted magnetic resonance imaging of ovarian tumors: differentiation of benign and malignant solid components of ovarian masses. J Comput Assist Tomogr. 2010;34(2):173-6.

Case 1. Endometrial cancer with deep myometrial invasion

A patient in her early 60s presented with atypical genital bleeding and was referred for an MR exam.

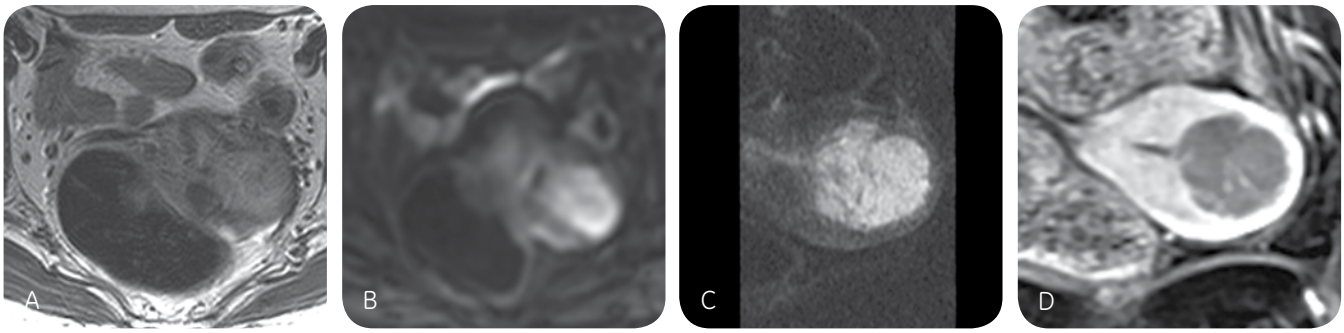

Figure 1. T2w (A) and conventional DWI (B) show a uterine corpus tumor, and the tumor/myometrial interface is indistinct. Oblique-axial (short axis of the uterus) FOCUS DWI (C) increases the conspicuity of the tumor-myometrial interface, and the residual myometrium is clearly demonstrated compatible with oblique-axial 3D CE-T1w with fat suppression (D).

Case 2. Ovarian cancer

A patient in her late 60s complaining of abdominal fullness was referred for an MR exam to help determine the cause.

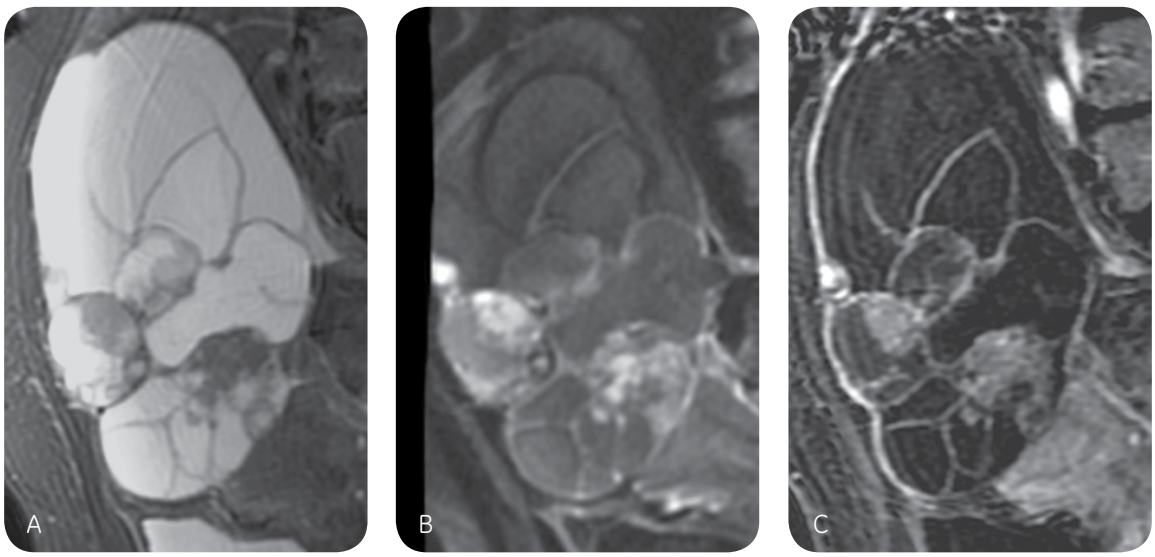

Figure 2. Sagittal T2w with fat suppression (A) shows a large ovarian multiloculated cystic mass with solid components. Sagittal FOCUS DWI (B) reveals high signal intensity solid cancer tissues within the cystic mass consistent with the sagittal 3D CE-T1w with fat suppression (C).

Case 3. Uterine sarcoma

A patient in her early 60s with abdominal distension was referred to MR to help determine if the swelling was due to air (gas), fluid, or other underlying cause.

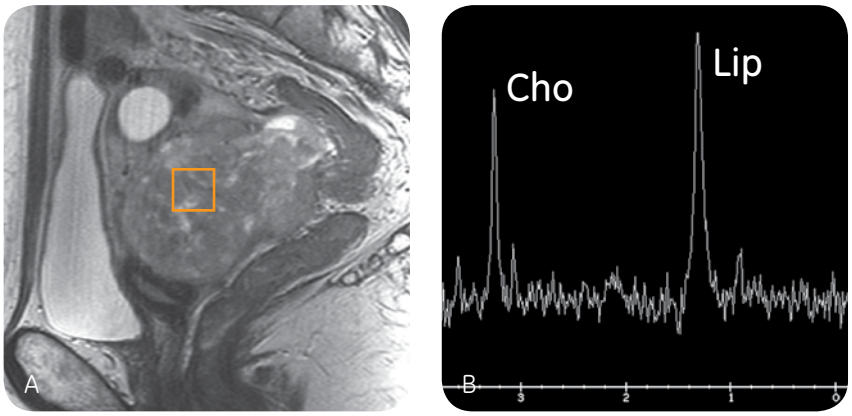

Figure 3. Sagittal T2w (A) shows a large heterogeneous uterine mass. MRS shows bimodal high choline (Cho) and high lipid (Lip) peaks, which are suggestive of the highly malignant nature of the tumor.

Parameters	
Device:	Signa™ HDxt 3.0T
Sequence:	Point resolved spectroscopic sequence (PRESS)
Shimming:	Automatic
Mode:	Single voxel (8 mL)
TR:	2,000 ms
TE:	144 ms
Measuring time:	4:56 min.

Parameters for Case 3 and Case 4

Biochemical diagnostic imaging in the female pelvis using proton MR spectroscopy

Proton MR spectroscopy (MRS) can image tissue metabolite concentrations along a spectrum based on the chemical shift phenomenon. MRS provides metabolic information and may add valuable information in assisting the clinician to distinguish between benign and malignant tumors. MRS may also aid the clinician to help them estimate the specific histological subtypes of gynecologic pathologies.[3, 4, 5, 6, 7]

High choline concentration in solid tumors is suggestive for malignancy; however, massive necrosis in high-grade malignant tumors may reduce choline signal. Additionally, necrosis-associated high lipid peak (1.3 ppm) is suggestive for malignancy. Myogenic creatine (3 ppm) for uterine leiomyomas, N-acetyl mucinous compounds (2-2.1 ppm) for mucinous tumors, and intracellular lipid for functioning ovarian tumors (i.e. thecomas) may provide specific metabolic information for tissue characterization. Acetate (1.9 ppm) and succinate (2.4 ppm) resulting from the enhanced glycolysis and fermentative pathways are suggestive for abscess with anaerobic infection and useful in differentiating from aerobic or sterile abscesses, or malignant tumors with necrosis.

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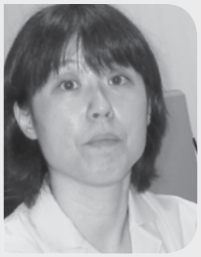


Case 4. Pyometra with anaerobic infection

A patient in her late 60s with atypical genital bleeding and no fever was referred for an MR exam.

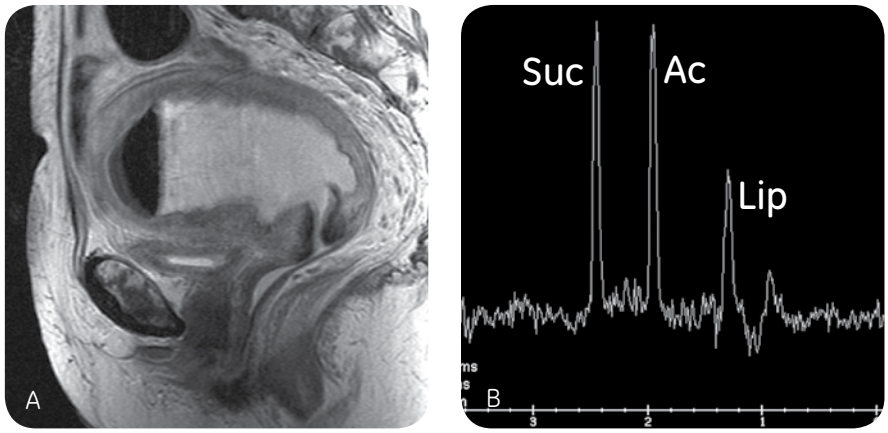


Figure 4. Sagittal T2w (A) shows an enlarged uterus and fluid-filled endometrial cavity with air-fluid level. MRS shows high lipid (Lip), acetate (Ac) and succinate (Suc) peaks, which are suggestive of anaerobic infection.

Discussion

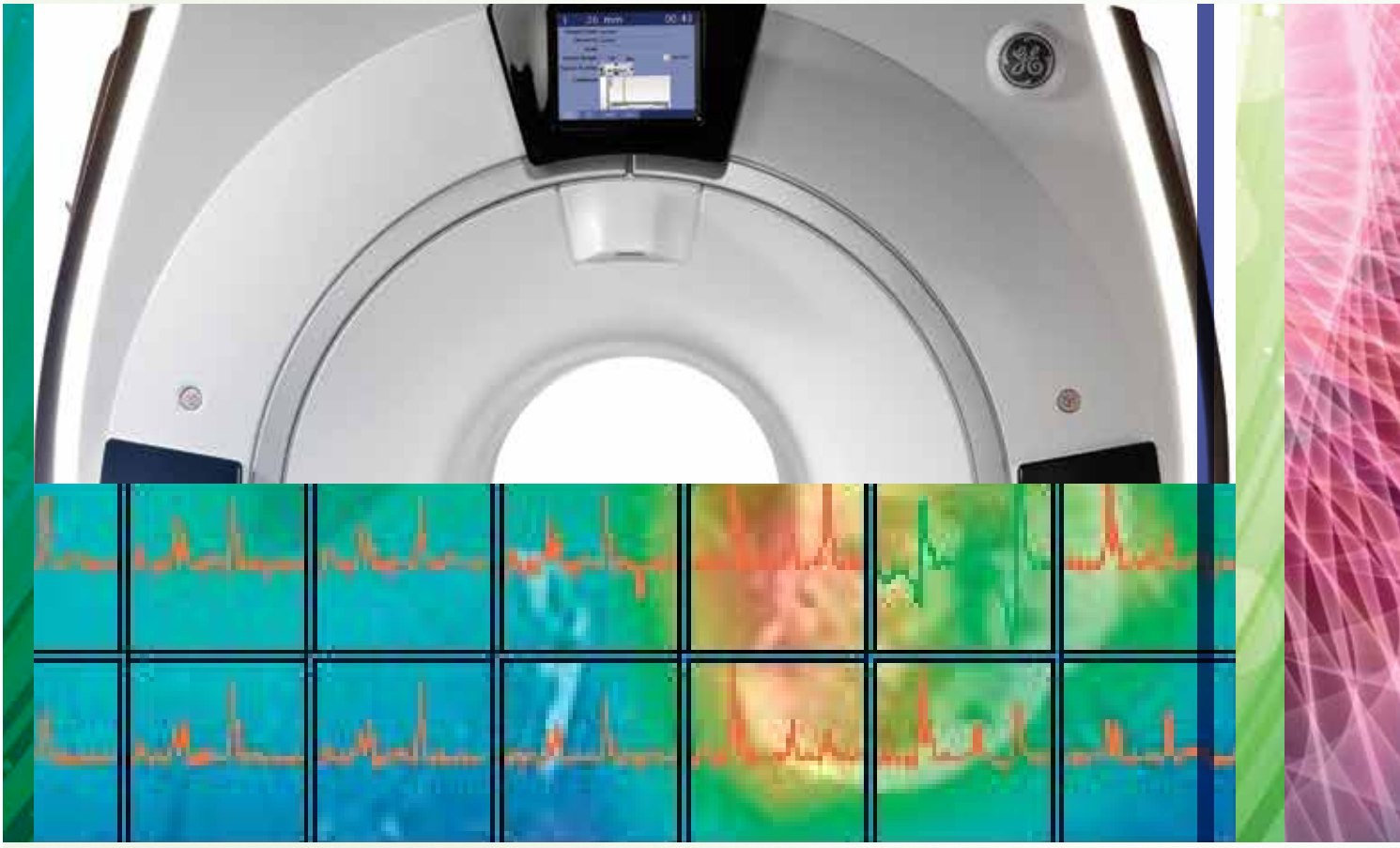
High-field 3.0T MR can offer high-quality MRS due to its ability to provide excellent spectral separation and increased signal-to-noise ratio. MRS can provide information on the level of choline, in this case 3.2 ppm, which is common in active proliferating tumors.[3, 4, 5, 6, 7] MRS may also be useful to the clinician to assist them in determining specific diagnosis of some pathologies based on the tissue characterization with various metabolites.

References

3. Takeuchi M et al. Differentiation of benign and malignant uterine corpus tumors by using proton MR spectroscopy at 3T: preliminary study. Eur Radiol. 2011;21(4):850-6.
4. Takeuchi M et al. Preliminary observations and clinical value of N-acetyl resonances in ovarian tumours using in-vivo proton MR spectroscopy at 3T. Eur Radiol. 2011;21(12):2640-6.
5. Takeuchi M et al. Preliminary observations and diagnostic value of lipid peak in ovarian thecomas/fibrothecomas using in vivo proton MR spectroscopy at 3T. J Magn Reson Imaging. 2012;36(4):907-11.
6. Takeuchi M et al. Preliminary observations and clinical value of lipid peak in high-grade uterine sarcomas using in vivo proton MR spectroscopy. Eur Radiol. 2013;23(9):2358-63.
7. Takeuchi M et al. In vivo proton MR spectroscopy in uterine abscesses. J Magn Reson Imaging. 2013;38(4):955-7.

Mayumi Takeuchi, MD, PhD, *is an Associate Professor at Tokushima University Hospital in Tokushima, Japan, where she also earned her medical and post-doctorate degrees. Dr. Takeuchi has received numerous awards, including three Cum Laude (most recently in March, 2015), one Magna Cum Laude from the European Society of Radiology, and eight Certificate of Merit from RSNA, most recently in December, 2013. She has published extensively on the topic of MR imaging in the female pelvis.*

Tokushima University Hospital, *located on Shikoku Island in Japan, was established as a national university in 1949. Since 1994, the facility has been using GE MR technology, and in 2003 became the first clinical site in Japan with a 3.0T scanner. In its fiscal year ending March 2013, the hospital provided medical services to over 214,600 inpatients and over 322,400 outpatients.*



With New Release of READY View, Seeing is Believing

To see a more complete picture of a patient's condition, more radiologists are utilizing MR exams that combine several tests—traditional, spectroscopic, and dynamic contrast enhanced MR, as well as diffusion-weighted imaging—to better assist the clinician in disease diagnosis. Multi-parametric MR can also help clinicians biopsy lesions, such as in the prostate, in a more targeted fashion.

DIGITAL DIVE
To watch a READY View video visit: tiny.cc/sps154

While extremely useful, quantifying the information from multi-parametric MR studies can be very challenging and time consuming. Because MR is a unique modality that's complex and capability-rich, it's critical for clinicians to have a dedicated, accurate, easy-to-use visualization application that supports multi-parametric and functional imaging analysis. To address this need for an advanced 3D post-processing application, GE Healthcare recently introduced the new release of READY View available on the AW Server 3.1.

The primary objective of READY View is to streamline the processing and analysis of MR functional data by providing intuitive and guided workflows, intelligent display based on smart layout technology, and full flexibility to customize applications. "The MR industry had a serious need for a 'go to' visualization tool," says Patrice Hervo, MR Visualization Development Manager with GE Healthcare. "READY View helps clinicians get the most from multi-parametric exams by enabling analysis of MR data sets with multiple images for each scan location. By

> "READY View helps clinicians get the most from multi-parametric exams by enabling analysis of MR data sets with multiple images for each scan location."
>
> *Patrice Hervo*

designing their own protocol, clinicians can now customize and personalize the way they interact with the output, which is a quantum leap toward image analysis standardization."

The multi-parametric approach

READY View provides a combination of protocols, applications, and advanced tools that enable a fast, easy, and quantified MR analysis. In addition to standard protocols, it offers fast and accurate multi-parametric protocols that boast an updated, simple, and intuitive workflow to display all derived functional outputs on a single screen.

Additionally, READY View allows the clinician to process dynamic or functional volumetric data and generate maps that display changes in image intensity over time, echo time, b-value (diffusion imaging), and frequency (spectroscopy). The combination of acquired images, reconstructed images, calculated parametric images, tissue segmentation, annotations, and measurement performed, enables a thorough multi-parametric analysis.

These specialized MR methods have evolved to the point where they are able to provide certain measurements of tissue properties. A multi-parametric MR approach generates images showing zones within a lesion that reflect heterogeneity and often display characteristic patterns. These attributes have proven to be useful in the detection of tumors, monitoring tumor growth, and guiding biopsies. Consequently, multi-parametric studies may provide clinically relevant information for the clinician in the diagnosis of neurological and oncological diseases.

Specialized MR acquisition methods such as diffusion weighted, dynamic contrast enhanced or dynamic susceptibility, spectroscopy, relaxometry, and other functional methods have evolved to enable quantification of tissue properties. Along with Brain View (brain-specific imaging data sets), Body View (time series data from body studies), and MR Touch (identifies variations in liver tissue stiffness), READY View offers a very unique combination of advanced processing tools to analyze functional MR images.

Customize and synchronize

READY View goes well beyond the traditional concept of user preferences by offering customization, personalization, and substantial flexibility. Any layout, functional protocol, or multi-series protocol can be edited, modified, and saved with a new name to fit personal or institution requirements for the review of a previously acquired data set or any new one.

Additionally, because MR is prone to patient motion during and between data acquisition, image interpretation can become quickly problematic if series alignment is suboptimal. To address this issue, clinicians can select READY View's Integrated Registration option to retrospectively register a series to another one defined as a reference—either automatically at image loading or manually by the user during the review session. Also, to improve Dynamic Susceptibility Contrast Weighted outputs, intra series rigid-body motion correction can be applied from the BrainStat AIF protocol to realign the brain anatomy.

To help clinicians process and analyze MR images anytime and anywhere there is an Internet connection, READY View, thanks to thin client technology, is accessible from PCs and PACS—allowing clinicians access to process and analyze images in any office, meeting room, or even at home.

READY View also offers features that can greatly facilitate research activities. For example, the application simplifies workflow to define a Region of Interest (ROI) as reference and show

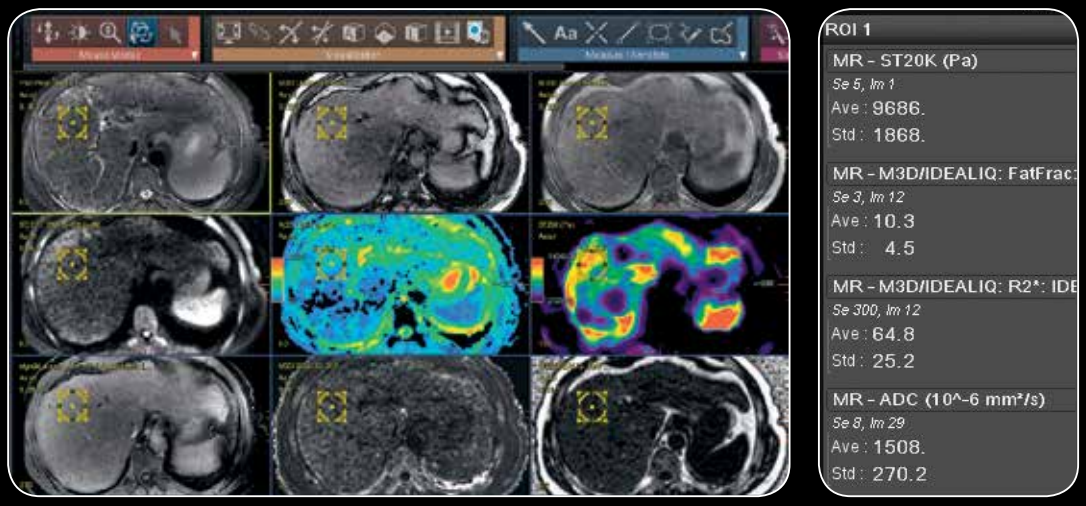
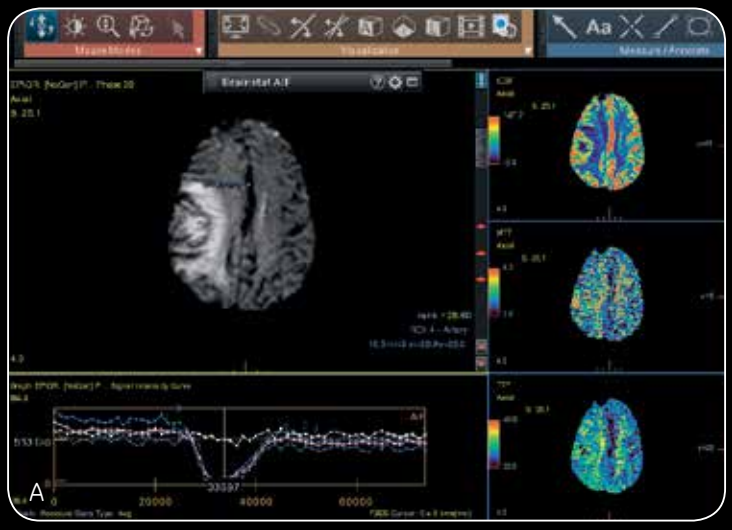


Figure 1. Example of a multi-parametric layout for a patient with alcoholic cirrhosis. Top row viewports: T2 PROP/FSE, In-Phase, Out-of-Phase. Middle row: DWI, ADC map, stiffness map. Bottom row: Dynamic LAVA, R2* map, Fat Fraction. Notice the high stiffness value (9.6 kPa) related to the high fibrosis stage, the mild Fat Fraction increase (10.3%), the normal range ADC value (1508.10-6 mm^2/s), and R2* value (64.8 Hz).



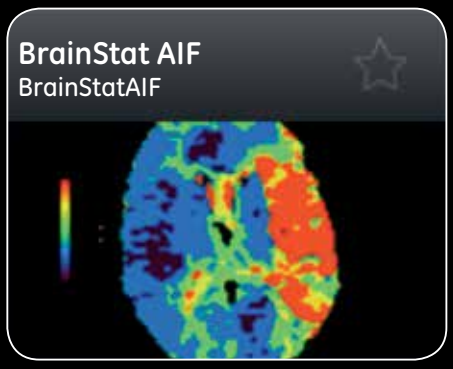


Figure 2A. BrainStat AIF factory protocol: factory icon and layout of BrainStat AIF. Hemodynamic maps (rCBV, MTT, TTP) are generated and displayed using the default color ramp and kernel size.

Figure 2B. BrainStat AIF custom protocol: Layout was modified to display a large graph view. Different hemodynamic maps (rCBF, rCBF, Tmax) are generated and displayed with another color ramp and a larger kernel value. Once saved, a new protocol icon is added in the protocol page.

Figure 3A. Top row viewports: T2 FLAIR, DWI, ADC. Bottom row viewports: FGRE T2*, EPI T2*, Tmax. Obvious inter scan motion happened between the T2 FLAIR series and other series (DWI and FGRE T2*). Severe patient motion occurred during the perfusion series that resulted in In-Phase misalignment and poor quality of the Tmax map.

Figure 3B. Integrated Registration is used to retrospectively co-register the DWI and FGRE T2* to the T2 FLAIR. Motion correction option in BrainStat AIF is selected to realign all phases of the DSC scan. Notice the recovered shape of the brain anatomy on the Tmax map.

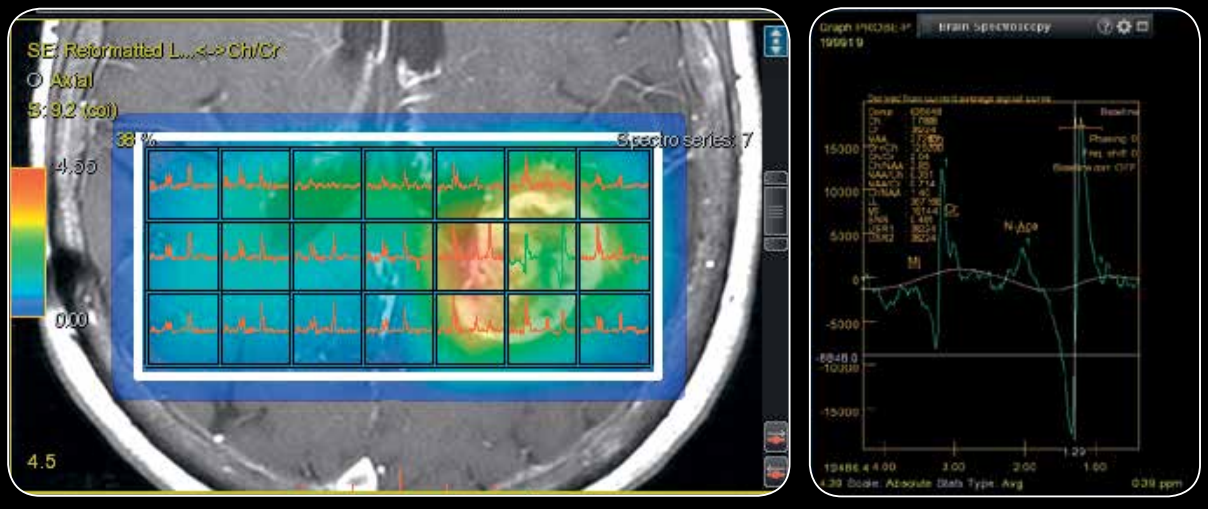


Figure 4. Spectra are displayed on top of the combined FSE T1w + contrast image and choline/creatine map.

percentage statistics in other ROIs; converts a segmented area into a ROI; offers auto contour segmentation based on functional threshold values; and allows exporting of ROI details and statistics from the summary table into a CSV file, as well as exporting graph data as CSV files. The READY View Brain Spectroscopy protocol is a perfect example, combining a simplified and intuitive workflow with advanced features.

"MR imaging continues to evolve rapidly, having grown from a variety of 2D acquisitions to a volumetric approach that requires high performance to manipulate large image volumes acquired as time-resolved series, or as functional acquisition like diffusion tensor imaging. Additionally, cross-modality efforts are made to provide common functionalities to review and process images across modalities in order to improve user experience. This is what drove the development of the new release of READY View," concludes Hervo.

Addressing Patient Motion in 3D Imaging

By Dan Rettmann, Scientist MR Applications and Workflow, and Patrick Quarterman, MR Clinical Specialist, GE Healthcare

Patient motion has endured as one of the most common barriers to achieving reliable diagnostic quality imaging, frequently requiring rescans or even callback examinations. The most common causes of motion in medical imaging include respiratory, cardiac, and bulk motion. The first two types of motion are often addressed using some type of physiological gating, triggering, or optimization of the standard MR parameters such as frequency and phase encoding direction. The third, bulk motion, is more difficult to predict or prevent and can be categorized into voluntary and involuntary bulk motion. Voluntary motions can often be mitigated by instructing the patient to remain still during the scan and by using immobilization techniques that may reduce patient comfort. In some situations sedation may be a means of addressing patient compliance; however, this may be undesirable. Involuntary motions, such as the hypnic jerk that so often occurs when the patient is falling asleep, or more devastating causes, such as neurodegenerative processes like Parkinson's disease, are more difficult to address and can severely degrade the diagnostic quality of the MR exam.

The issue of patient motion is of particular concern when using high-resolution three-dimensional (3D) imaging, which is becoming a preferred technique for imaging of the brain for structural anomalies and disease due to the increased detail and potential diagnostic confidence that it can offer radiologists. Unfortunately, 3D imaging techniques are more sensitive to patient motion because the spatial information is encoded over the full acquisition rather than on a slice-by-slice manner as is done in 2D imaging. Because of this, any motion that occurs during the acquisition results in artifacts that are propagated throughout all of the resulting images.

PROMO

A promising approach towards addressing patient motion is to modify the pulse sequence in real-time to follow the patient's movements during the acquisition—commonly known as prospective motion correction.[1] A general assumption made for motion correction of the brain is that it moves in a rigid fashion; that is, all portions of the brain move in the same manner or that it does not deform as it moves. The jaw and neck are examples of other anatomical features of the head that do not move rigidly, but rather stretch or rotate differently depending on which portion or how much of that anatomy is moving. Rigid body motion can be corrected for by adjusting the position and orientation, or pose, of the field of view (FOV) of the acquisition. In MR prospective motion correction, the FOV is adjusted by modifying the gradients and radiofrequency (RF) to correct for the position and orientation of the brain. Based on this principle, GE Healthcare, collaborating with researchers at the University of California, San Diego, has developed a motion correction technique called PROspective MOtion correction[2] (PROMO) that is optimized for 3D imaging and is currently available in the Cube T2 and T2 FLAIR sequences. PROMO adjusts the FOV during the scan to maintain anatomical correspondence to the original prescription.

Cube T2 and T2 FLAIR sequences are based on 3D fast spin echo and permit high resolution 3D volumetric imaging through the use of a variable flip angle refocusing echo train that reduces RF power. Cube T2 and T2 FLAIR sequences both have a longer repetition time (TR), 3 to 7 seconds, to permit signal relaxation. PROMO incorporates the collection of three-plane spiral navigator images during the inherent dead-time of the pulse sequence to detect any changes in patient position (Figure 1). The low flip angle spiral navigators have no discernable effect on the imaging and can be used to effectively measure subject motion with a high degree of accuracy. The navigator data is reconstructed and analyzed using an extended Kalman filter, a processing algorithm that can be performed in approximately 10 msec. The patient pose information produced by this processing is sent back to the pulse sequence which corrects for the computed patient movement in near real-time.

Because PROMO uses image-based navigators, the motion estimation can be focused on the brain itself. K-space based techniques can be corrupted by non-rigid body motion in the navigator's FOV, such as jaw or neck movement. By narrowing the motion estimation to movement of only the brain, common motions, such as swallowing or the bending of the neck, do not affect the quality of the motion correction.

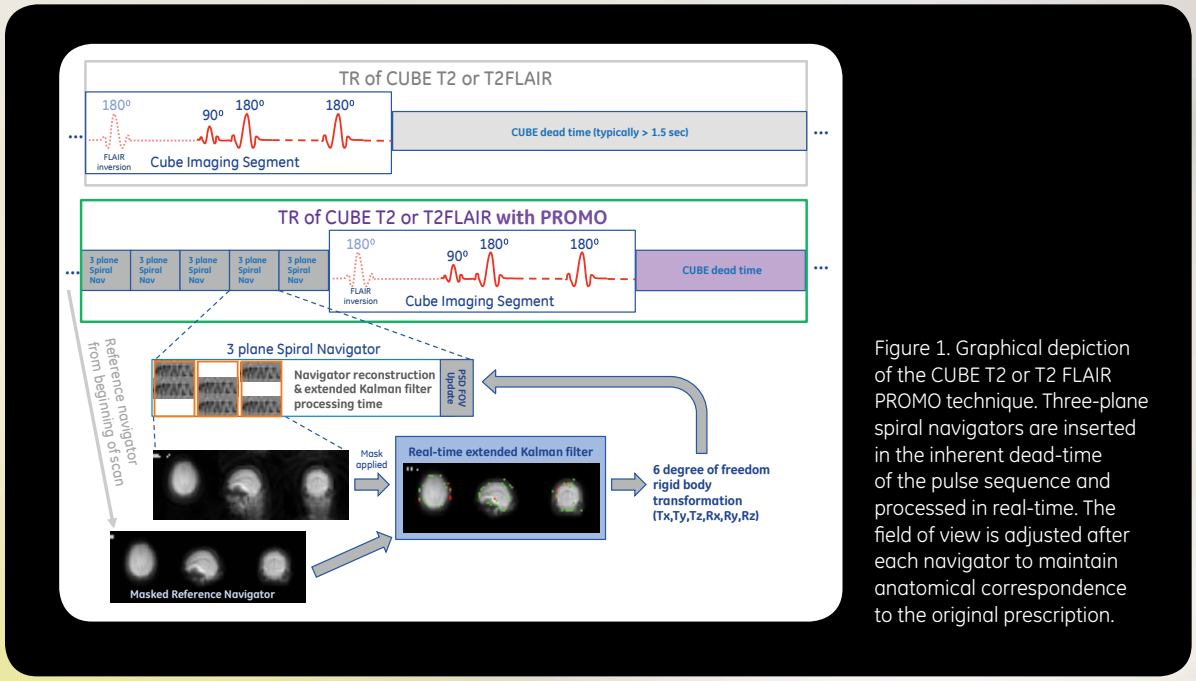


Figure 1. Graphical depiction of the CUBE T2 or T2 FLAIR PROMO technique. Three-plane spiral navigators are inserted in the inherent dead-time of the pulse sequence and processed in real-time. The field of view is adjusted after each navigator to maintain anatomical correspondence to the original prescription.

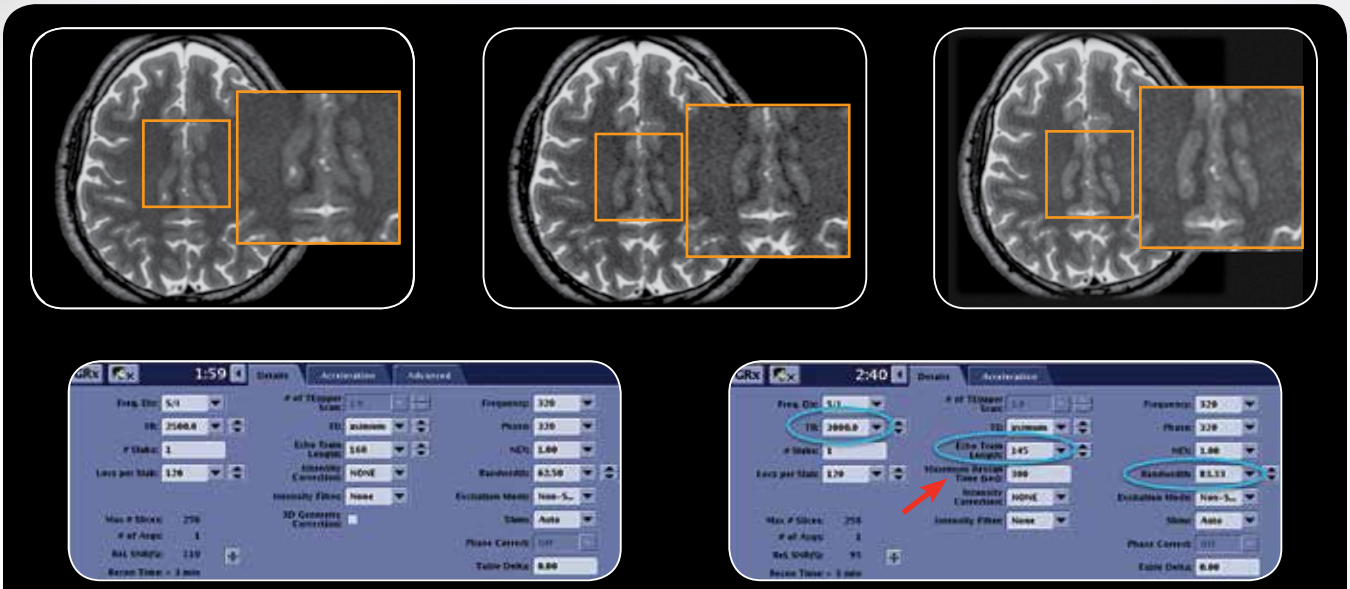
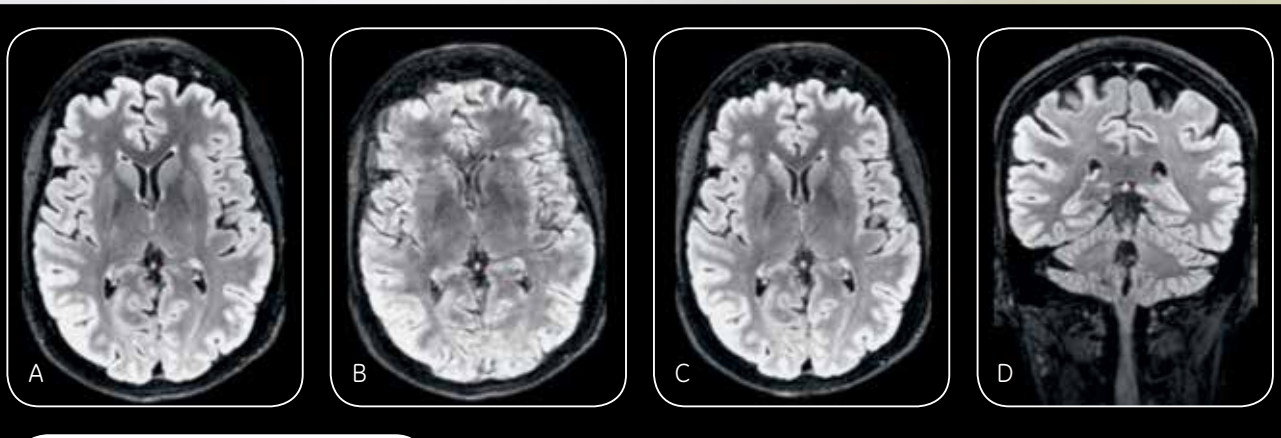


Figure 2. An example Cube T2 protocol (no subject motion, left) to demonstrate optimization of your Cube protocol. If PROMO is added without optimizing parameters (PROMO with subject motion, middle) one can perceive increased noise and blurring. By reducing echo train length by 15, increasing bandwidth by ± 20 kHz, and increasing TR by 500 ms near original image quality can be duplicated (PROMO with subject motion, right). The Maximum Rescan Time field (arrow) may be used to control the amount of additional scan time to add for reacquiring severely motion corrupted data, if necessary.

Bulk motion related artifacts are caused by a number of mechanisms[3] but for 3D brain imaging these artifacts are typically due to discontinuities in k-space, i.e., large signal changes between adjacent k-space lines. If prospective motion correction is used, and motion corrupted data acquired over the detection period (for Cube, a TR) is not reacquired, k-space discontinuities will likely exist and still result in ghosting artifacts or blurring in the images. To address this, a scan using PROMO can be configured to re-acquire data that was severely corrupted by motion using the Maximum Rescan Time field. This field provides the user the flexibility to specify the maximum amount of additional scan time they want to use to acquire the most severely motion-corrupted data, although if no or minimal motion occurred then no additional scan time will be necessary. Re-acquisition of the motion corrupted data will improve the resulting image quality as compared to performing the real-time FOV correction alone.

The main limitation encountered when performing any prospective motion correction is that there is no way to know a priori the magnitude of patient motion that the scan will have to correct. When a scan is prescribed, some MR parameters are internally optimized based on the orientation of the scan FOV with respect to the physical gradients of the MR scanner. To account for the unknown motion, the pulse sequence must usually optimize these parameters using a worst case condition. Therefore, when PROMO is used the echo spacing will be slightly longer than a scan without PROMO. The increased echo spacing will typically result in perceived blurring due to an increased T2 decay over the echo train but a slight loss of SNR is also expected. This effect can be mitigated by appropriately adjusting the scan parameters of a standard Cube T2 or T2 FLAIR protocol (Figure 2). To address the blurring, it is recommended that the echo train length be reduced by about 15 and receive bandwidth be increased by ± 20 kHz. Depending on the protocol, this change may slightly drop signal to noise; a small increase to the TR (200-500 ms) can resolve this.

With the release of the DV25.0 Continuum Pak™, there is a significant improvement to Cube T2 FLAIR, which now permits the use of the T2 preparation (T2 Prep) imaging option for enhanced visualization of white matter/gray matter contrast. In addition, the increased contrast to noise afforded by the use of T2 preparation enables even more flexibility in the optimization of the imaging parameters (e.g. the TR can be lowered by about 1 sec, reducing scan time). When T2 Prep is used with Cube T2 FLAIR and PROMO a high-contrast volumetric motion-robust scan can be achieved (Figure 3).



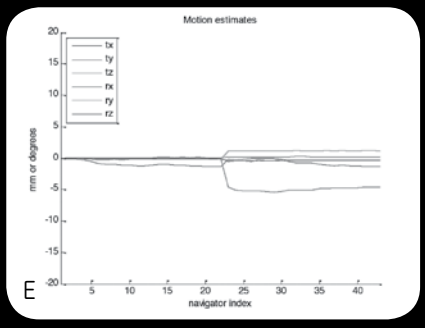


Figure 3. A demonstration of the benefits of PROMO when used with Cube T2 FLAIR and the new (in DV25.0 Continuum Pak) T2 Preparation imaging option. High white matter/gray matter contrast and increased CNR is matched with prospective motion correction to produce artifact-free images (C & D) when a scan with similar motion and without PROMO (B) would be non-diagnostic. This example also shows the effectiveness of the discussed scan parameter optimization strategy, resulting in nearly identical image quality with (C) and without (A) PROMO. The plot (E) shows the motion corrected for by PROMO and represents two common motions experienced while scanning, a slow relaxation and a quick side rotation.

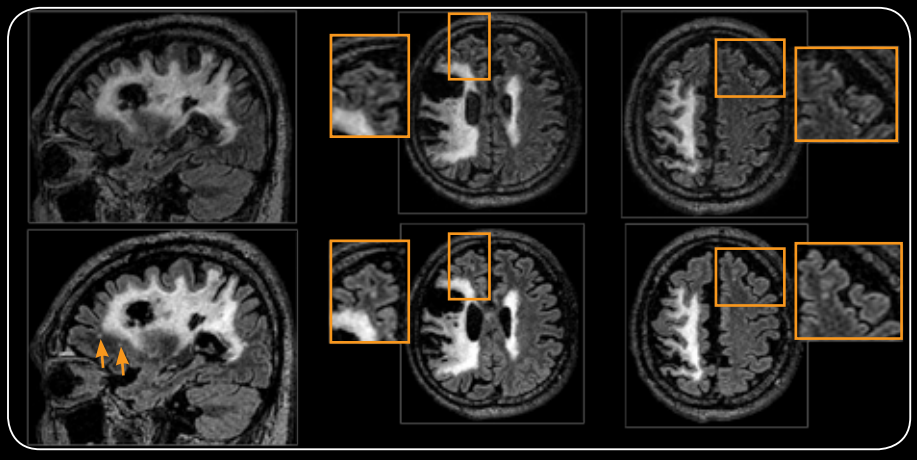


Figure 4. Cube T2 FLAIR images of patient from CHR Laennec Imaging Center, Creil, France using a MR450w. Patient motion with conventional Cube sequence will usually result in artifacts that can mask important findings (top row); incorporating PROMO into the protocol helps reduce the need for rescans and gives higher confidence no anatomy is missed.

Patient motion is a problem for everyone, and GE Healthcare is working hard to help customers obtain the best diagnostic image quality possible. Customers incorporating PROMO into their protocols are realizing the benefits and the possibilities for improving the efficiency of their practice. A motion-robust scanning protocol may be used to help reduce sedation rates in young or motion prone subjects. Reducing rescans by incorporating PROMO in protocols for elderly or severely sick populations is certainly imaginable (Figure 4). A comprehensive portfolio for motion robust imaging of the brain is an important goal for GE. With techniques like PROPELLER (T2, T2 FLAIR, T1 FLAIR and PD) for 2D motion robust imaging and now Cube T2 and T2 FLAIR with PROMO for 3D prospective motion corrected imaging, we are helping our customers make the most of their MR scanners.

References

1. Maclaren J, Herbst M, Speck O, Zaitsev M. Prospective motion correction in brain imaging: A review. Magnetic Resonance In Medicine 2013, 69(3), 621-636. doi:10.1002/mrm.24314.
2. White N, Roddey C, Shankaranarayanan A, et al. PROMO: Real-time prospective motion correction in MRI using image-based tracking. Magnetic Resonance In Medicine 2010, 63(1), 91-105. doi:10.1002/mrm.22176.
3. Zaitsev M, Maclaren J, Herbst M. Motion artifacts in MRI: A complex problem with many partial solutions. Journal Of Magnetic Resonance Imaging 2015. doi:10.1002/jmri.24850.

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