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Spring 2019

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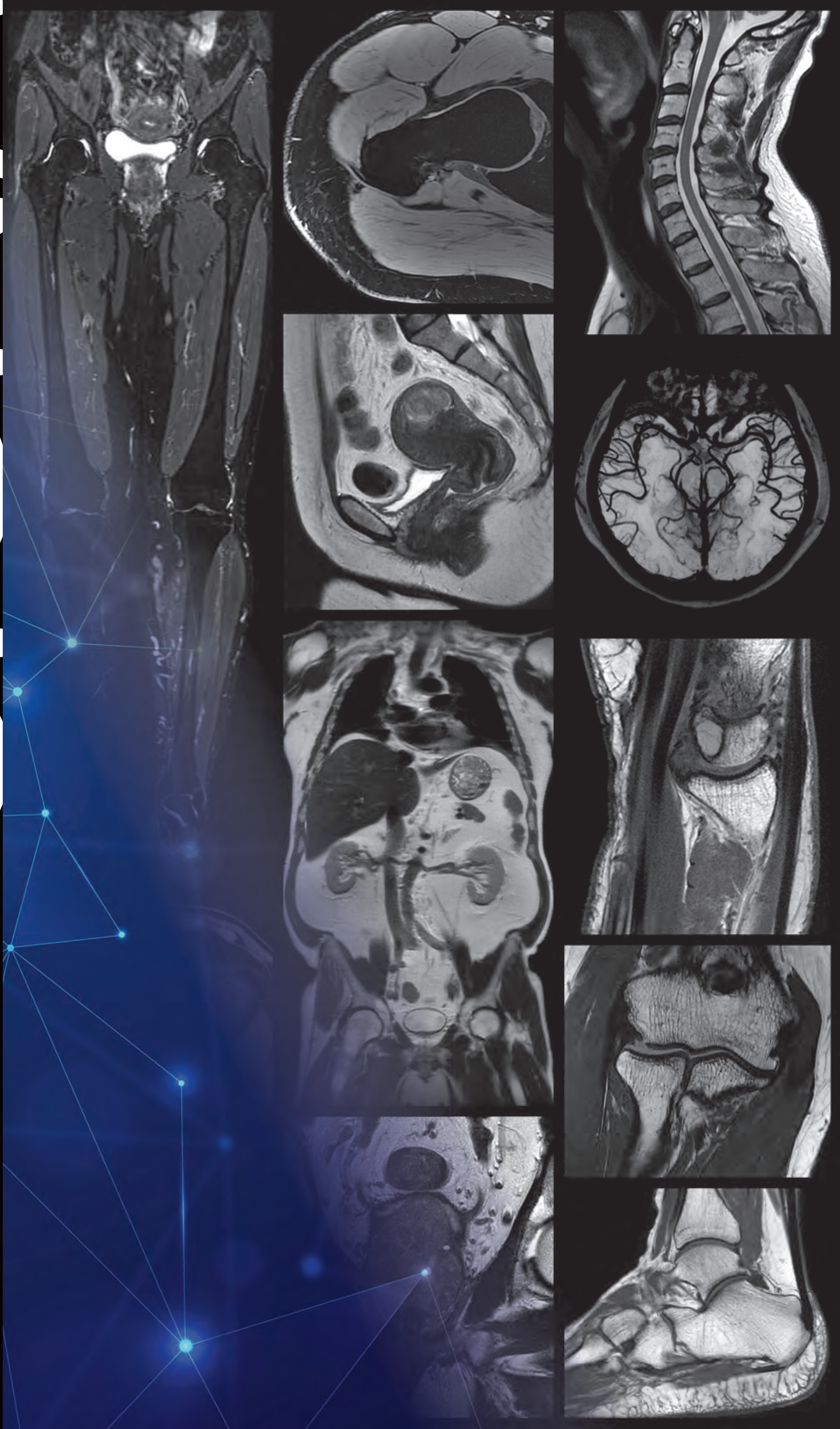

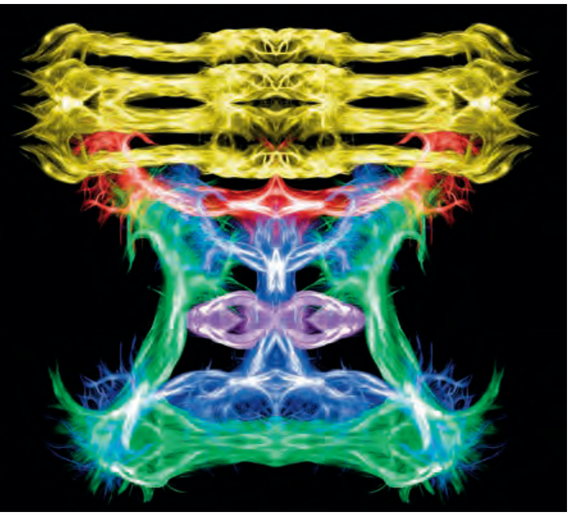

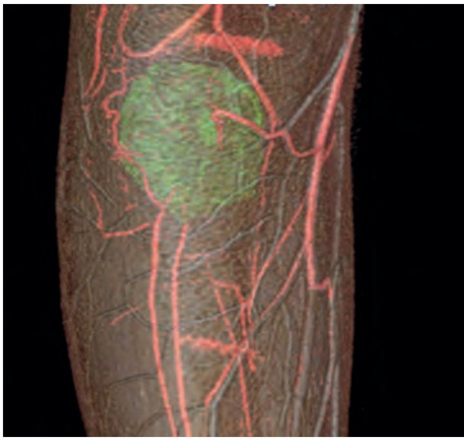

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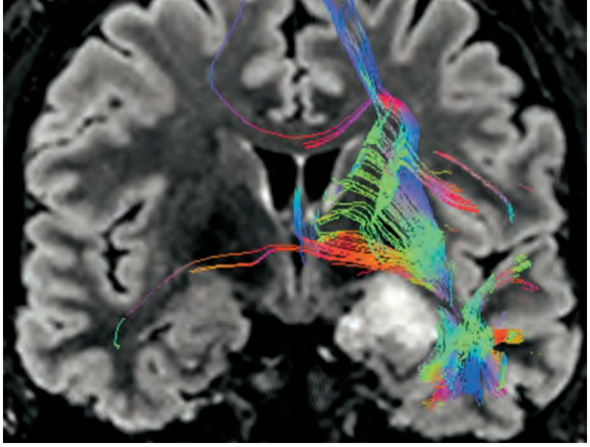

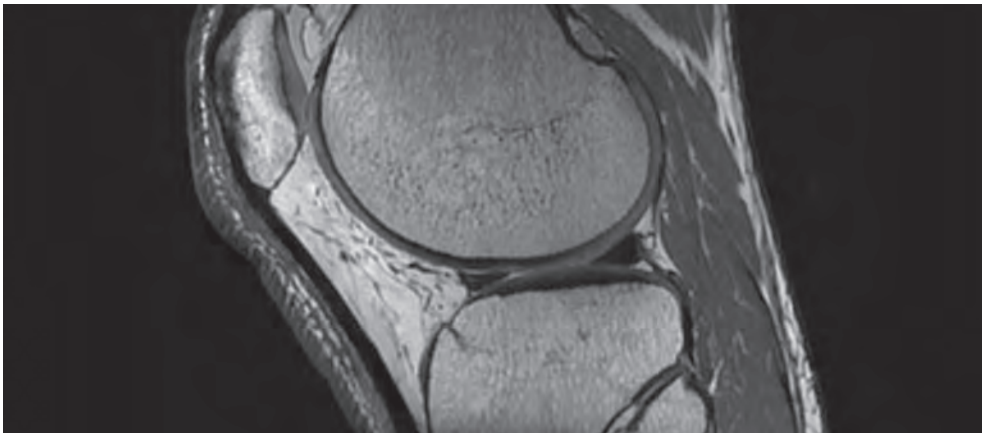

Case Studies

Tech Trends

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MR is elevating radiology and patient care

Welcome to the 2019 Spring Edition of SIGNA™ Pulse of MR. As the inaugural Guest Editor, I am honored and excited to share some of my thoughts with you. I hope that you will enjoy reading the many clinical and technical advancements highlighted in this issue; several are made possible by the collective effort of GE Healthcare's academic partners that further elevate radiology.

The past decade has truly been an exhilarating period with multiple advances converging, fueled by technological innovations. We've seen the extension of MR as a mostly diagnostic tool into the realm of therapy and preventive healthcare. Indeed, the field of MR, whether in the clinic or research center, has been technology driven. There is a constant thirst for higher field strengths, stronger gradient power, more RF channels and faster imaging speeds, leading to more efficient and precise ways of gathering knowledge. While these front-end innovations in image acquisition are continuing, there is a recent revolution in data sciences encompassing the full span of an MR workflow. With the emergence of artificial intelligence (AI) and machine learning (ML) algorithms, we may exact, analyze and share much richer and more detailed information than previously possible. For example, AI and ML embedded on the MR scanner may help enhance consistency in image acquisition and raise the probability for great results. Other advances may help increase the amount of information available to us for disease diagnosis and for guiding therapeutic interventions.

AI may also assist in our ability to detect diseases at an early stage when treatments may be most effective. Importantly, together AI and ML bring the latest technologies to all corners of the world.

Articles in this issue are partial reflections of this exciting evolution. On the expanding roles of MR, for example, we see how the development of an MR-only planning workflow at Skåne University Hospital, Sweden, is changing our way of performing radiation therapy; we see that the use of PET/MR at the Medical College of Wisconsin and Children's Hospital of Wisconsin is facilitating pediatric cancer staging and restaging; and we see that whole-body diffusion MR at PRIISM, EHP Kara in Algeria allows metastatic lesion detection. The never-ending technological innovations continue to remove traditional obstacles and open new avenues. For example, the integration of HyperSense acquisition for accelerated scanning and next-generation body navigators are making free-breathing MR a reality for body applications (see case study from Medipole de Savoie). The adoption of high-channel count arrays, increased gradient performance and fast imaging techniques now offer unprecedented and exquisite details of the human brain (see 48-channel Head Coil case study from RNR). The infusion of AI and deep learning algorithms are helping to automate workflow (see article on **AI**Rx™‡ at Fairfax Radiological Consultants) and making the MR images more informative and accessible.

In addition to these developments at the forefront, it is worth noting that GE is also making a concerted effort to extend its cutting-edge technologies across the product portfolio, making them accessible to all. For example, the industry-first AIR Technology™‡ that has demonstrated its superiority on the top-of-the-line SIGNA™ Premier platform has been migrated to the SIGNA™ Architect platform (see articles featuring The Queen Silvia Children's Hospital, Osaka University Hospital and Kawasaki Saiwai Hospital), thus benefiting a wider population.

Using somewhat fitting jargon, I feel that this issue is a "HyperSense" sampling of all the MR advances happening at GE, from which you can hopefully reconstruct and infer a more complete image of GE MR today. From high-power gradient systems, the transformative and comfortable AIR Technology™ Suite, innovative pulse sequences, to new applications in the brain and body; from disease diagnosis, to therapy and monitoring patients with chronic disease; from leading MR centers to rural corners of the world, GE MR is bringing great things to, and elevating the quality of, life. Ⓢ

Allen Song, PhD,
Director of the Duke University Brain Imaging and Analysis Center and Professor of Radiology at Duke University, Durham, NC

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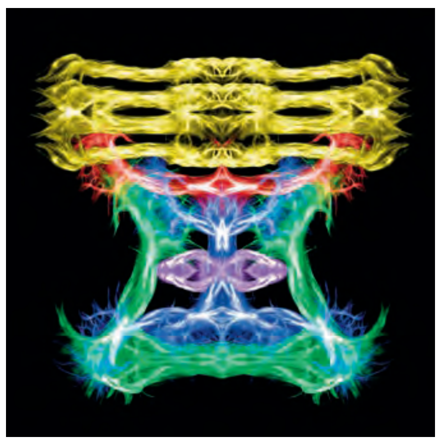
Leading the AI charge

While certain aspects of healthcare aren't expected to feel the effects of artificial intelligence (AI) for some time, radiology is often cited as an area that will first feel its impact. Dr. Mark Michalski, Executive Director of the MGH & BWH Center for Clinical Data Science, recently weighed in on why he feels radiologists are uniquely positioned to advance AI in an interview for GE Healthcare's The Pulse news website. In the interview, Michalski stated that the most recent advances in machine learning—such as deep learning—work very well with image and video data, so radiology and other specialties that use image data (like pathology, dermatology, ophthalmology, or radiation oncology and others) have been among the first impacted. Beyond this, radiology has a relatively well-structured set of data, which is the foundation for building machine intelligence. Michalski also noted that the radiology community already has made significant investments in IT and tech infrastructure—it is generally familiar with high tech systems (like scanners, integrations with EHRs, etc.), making adoption and integration of machine learning technologies perhaps easier.



Artful images

Dr. Denis Ducreux, a French radiologist, Professor of Neuroradiology at University of Paris-Sud, and Head of the Diagnostic Neuroradiology Department at Bicêtre Hospital in France, has been creating artistic renderings from MR images for 15 years. Since 2017, he's been using the 3.0T SIGNA™ Architect to capture the raw MR images. He then processes using BrainAnalyst, a research-use only neuroimaging software he developed that tracks fibers in the brain.

Dr. Ducreux says all of his artistic images focus on the limbic system because it is the center of the unconscious. Although he does not use the artistic images for diagnostic purposes, he says studying the limbic system is critical to research to help understand how humans' emotional processing works.

SIGNA™ Pulse of MR survey

What's on your mind? The editors at SIGNA™ Pulse of MR want to know. Help us improve the content of our magazine by taking our survey at: http://tinyurl.com/sps191

Global MR market size to grow

In January 2019, Technavio released their research report on the Global MRI Systems Market for the forecast period 2019-2023. This market analysis report segments the market by product (closed MR systems and open MR systems) and geography (the Americas, APAC, and EMEA).

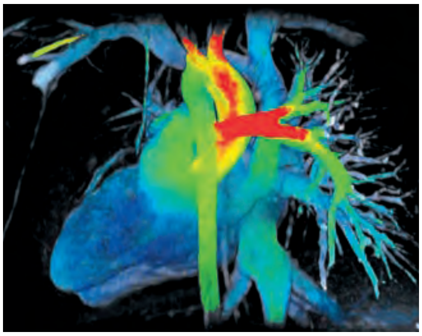
The report stated that the market size for global MR systems will grow by almost 1.58 billion USD during 2019-2023, at a Compound Annual Growth Rate of more than 5%. Body imaging was cited as one of the fastest-growing applications of MR.

Source: businesswire.com

More comfortable prostate scans

Imaging the prostate is now a lot less embarrassing and more comfortable for patients. The clinicians at the Surp Pırgiç Armenian Hospital in Istanbul, Turkey, are using a new imaging process on their 3.0T SIGNA™ Pioneer system with Total Digital Imaging (TDI) that eliminates the use of the endorectal coil in MR prostate exams. The coil can be eliminated because of the scanner's dramatically high signal-to-noise ratio results. In addition to making the exam more comfortable, the new process helps patients get in and out of the scanner faster, creating a boost in productivity.

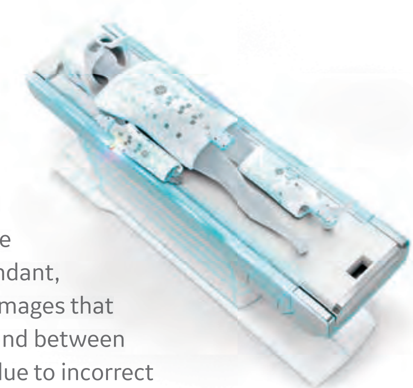
University Hospital Quirónsalud in Madrid is pushing to new limits by using Multiparametric Magnetic Resonance (RMmp), an MR imaging technique that allows them to non-invasively study the prostate. This exam helps detect the volume of a tumor and can track the progression of its development, a key element in properly diagnosing and treating the disease.



Video game tech fueled ViosWorks

Many of you have read about GE Healthcare's groundbreaking MR software solution, ViosWorks, that can complete a scan of cardiovascular anatomy, function and flow in 10 minutes or less—an astonishing time savings compared to historical cardiac exam times of one to two hours. What you may not know is how the solution leveraged video game technology to overcome a major hurdle. In an article for GE Healthcare's The Pulse, Dr. Albert Hsiao, co-developer of ViosWorks, said that when he first started adjusting MR scanners to capture information for his software, they captured so much data, the computers couldn't process it all into images doctors could interpret. To address this hurdle, Dr. Hsiao and Arterys™, a company Hsiao co-founded to specialize in web-based medical imaging analytics powered by AI, looked to the technologies behind modern 3D video games to distribute large amounts of 3D data across many graphics processing unit (GPU) cores. With this approach, Arterys™ was able to develop a cloud-based system to manage and rapidly process the gigabytes of MR data behind each cardiac image.

Clear the AIR



GE Healthcare's **AI**Rx™‡ technology was cleared by the FDA in January 2019. This AI-based, automated workflow tool for brain scanning is designed to increase consistency and productivity by providing automated slice prescriptions to help reduce previously redundant, manual steps. **AI**Rx™ is intended to produce images that have less variability between technologists and between scans to help lower the chances for retakes due to incorrect slice placement.

How does it work? **AI**Rx™ features a pre-trained neural network model that leverages deep learning algorithms and anatomy recognition to define the correct anatomical landmarks and automate the scanning process for routine to challenging setups. The algorithm automatically aligns the scan prescription to anatomical references that are based on a database of over 36,000 images sourced from clinical studies and reference sites. **AI**Rx™ is built on Edison, GE Healthcare's new artificial intelligence platform.

And speaking of air, GE Healthcare's AIR Technology™ RF coils received FDA clearance for 3.0T and 1.5T systems in November 2018.‡ The current suite consists of a 30-channel Anterior Array (AA), a 21-channel large Multi-Purpose (MP) Coil and a 20-channel medium Multi-Purpose (MP) Coil. This industry-first suite of RF coils enables freedom in coil positioning and handling during a scan. For example, the AIR Technology™ AA is 60 percent lighter than a conventional, hard-shell AA.

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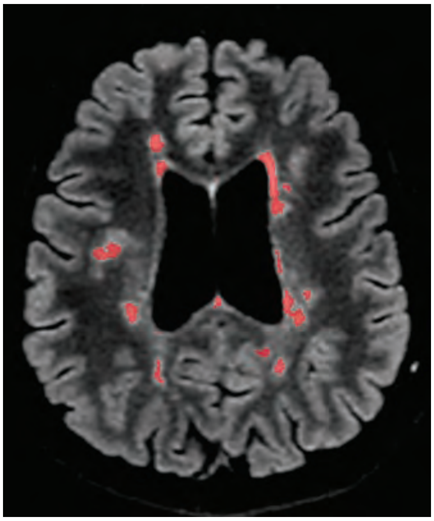
Read more about **AI**Rx™ on page 37.

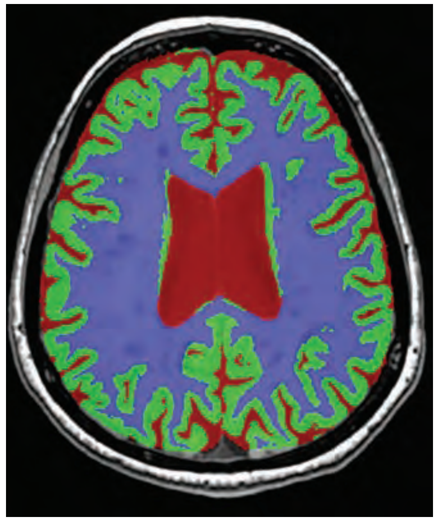
EPI in the mix

Anna Falk Delgado, MD, PhD, specialist physician at Karolinska University Hospital, Tim Sprenger, PhD, Clinical Scientist, GE Global Research and Stefan Skare, PhD, Associate Professor and MR physicist at Karolinska Institutet, received the 2018 Athena Prize for shortening the time for an MR exam from one half hour to one minute. Their work focused on developing software that controls the MR system so it could produce images in less time, but still ensure the images contained enough information for diagnoses. Typically between five and 10 different types of MR sequences are needed for an MR exam, and each imaging series may take up to seven minutes. Skare however, noted that the EPI imaging method is around 100 times faster than other MR imaging methods. Skare asked himself, what if you used the quick method to take all types of MR images? This led Skare's team to develop a method called EPI Mix that allows all images to be captured in 70 seconds instead of 20-30 minutes. The group is now planning further studies to compare conventional MR imaging and EPI mix.

SIGNA Pulse of MR – digital library

View this issue and those from the past at: www.gesignapulse.com





MR optimizes diagnoses and long-term patient management

GE Healthcare was recently featured in USA Today for how MR technology optimizes diagnosis and long-term treatment. The article cited several new MR technologies from the company which are making it easier for patients to undergo the scans and doctors to use MR imaging for diagnosing neurological diseases and disorders. These technologies include **AI**Rx™, which uses a deep-learning approach to automatically detect and suggest “slices” for neurological exams and deliver consistent and quantifiable results from scan to scan.‡ Also mentioned is Quantib™ Brain software which uses machine learning to identify where lesions are in a patient’s brain, while color coding new and old lesions and measuring brain volume.

From a comfort point of view, these technologies are making an impact. “No matter how the patient’s head is positioned, **AI**Rx™ will place those slices in the same location, reducing variation amongst technologists,” says Heide Harris, Global Product Marketing Director, MR Applications and Visualization for GE Healthcare.

Technology advances from GE Healthcare have also increased exam speed. Ten years ago an exam took 25-35 minutes but with the latest advances many exams can be completed in about 10 minutes.

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Read the full article at:
tiny.cc/sps194

European team awarded 3.2M grant

In December of 2018, GE Healthcare’s MR team in Hungary won a $3.2M grant from EIT Health to work with customers to streamline the delivery of radiation therapy (RT). Approximately one in three people will develop cancer in their lifetime and about half of these patients will experience RT. Today’s RT workflow is quite complex, time-consuming, costly and stressful for anxious patients. One of the goals of the research is to develop and produce a silent, one-stop, MR-only RT solution, leveraging the full potential of multi-parametric MR and deep learning artificial intelligence.

Members of the GE Healthcare team include Florian Wiesinger, PhD, Principal Investigator, Timo Schirmer, PhD, and Senior Scientist Cristina Cozzin, PhD. Clinical partners for clinical development, assessment and patient scanning include New Castle University (Prof. Hazel McCallum and Prof. Ross Maxwell) and Erasmus Medical Center (Prof. Steve Petit and Prof. Juan Hernandez Tamames). Additionally, the team is partnering with the Technical University Munich, King’s College London, Szeged University and SyntheticMR.

The EIT Health grant focuses on healthcare innovation. The organization cited GE Healthcare’s great reputation regarding pseudo CT image conversion, deep learning, silent imaging and parameter mapping as a key reason for the award.

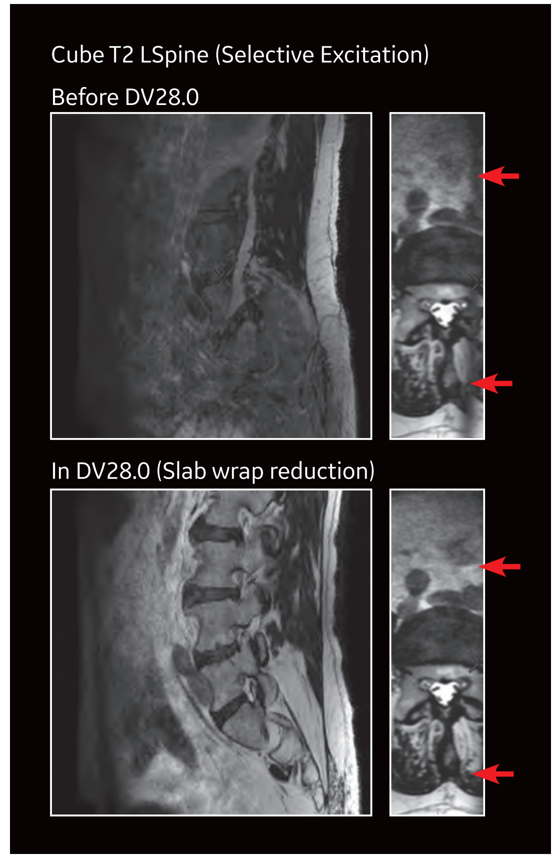
To learn more about the grant, visit:
https://www.eithealth.eu/.

New software release focuses on enhancements

Consistent, excellent image quality is not only one of the top needs from MR customers but also the bread-and-butter of the MR modality. Therefore, GE Healthcare MR never stops looking at existing applications and analyzing what can be done to further improve them. According to Wei Sun, Engineering Manager for MR Pulse Sequence/ Applications Development at GE Healthcare, MR users will be thrilled with some of the enhancements the new DV28.0 software release will bring.

DV28.0, available mid-2019, will launch on the 3.0T product line first including SIGNA™ Premier, SIGNA™ Architect and SIGNA™ Pioneer, and will then integrate into our 1.5T products. It will feature enhancements to Cube, Cube T2 FLAIR, FSE T2 FLAIR, PROPELLER, LAVA, 3D FIESTA and other applications. The enhancements produce images with less wrap-around artifacts, darker backgrounds and higher contrast and SNR than prior generations.

The before and after DV28 images demonstrate remarkable improvements as illustrated in updates to Cube.



Cube enhancement

In DV28.0, the Cube pulse sequence waveform has been optimized to reduce slab wrap and echo space. As a result, SNR of Cube improves greatly with selective RF excitation. For non-selective RF excitation, the shading is also obviously reduced. In addition, a new image intensity correction algorithm, SCENIC, has been introduced to improve the left/right shading on Neuro. S

Localizing pain with PET/MR

The number of people who suffer from pain is striking. The Institute of Medicine (IOM) reports that over 100 million adults in the US have chronic pain, while worldwide, 1.5 billion individuals suffer from pain related to cancer treatment and other conditions. As doctors and patients look for ways to address pain beyond the use of prescription medications, the work of Dr. Sandip Biswal, Associate Professor of Radiology (Musculoskeletal Imaging) at the Stanford University Medical Center, becomes all the more pertinent.

Dr. Biswal and his team have been developing clinical imaging methods to objectively pinpoint the site of pain generation using novel agents that specifically seek out molecular and cellular pain markers to highlight hypersensitive pain-sensing nerves.

Two recent studies led by Dr. Biswal highlight the use of PET/MR in localizing pain. In the first study using the SIGNA™ PET/MR, Dr. Biswal studied the feasibility of using an ^{18}F-FDG PET/MR approach for improved diagnosis of chronic sciatica. In the study of nine patients with chronic sciatica and five healthy control volunteers, significantly increased ^{18}F-FDG uptake was observed in detected lesions in all patients and was correlated with pain symptoms. ^{18}F-FDG-avid lesions not only were found in impinged spinal nerves but also were associated with non-spinal causes of pain, such as facet joint degeneration, pars defect or presumed scar neuroma.

The second study focused on localizing knee pain in a 50-year-old patient. In the study, the patient's chronic knee pain was resolved by removal of an intraarticular synovial lipoma, which had shown increased uptake of the novel, Sigma-1 receptor specific radioligand ^{18}F-FTC-146 on simultaneous PET/MR. It was noted that the patient had previously undergone a variety of unsuccessful orthopedic surgeries and denervating interventions. The study illustrated the promising application of ^{18}F-FTC-146 PET/MR as an improvement over MR alone as an imaging modality for detecting pain generators.

Further studies to validate using PET/MR to localize pain could potentially facilitate, among other things, more intelligent management of chronic pain. S

Lars E. Olsson, PhD
Skåne University Hospital
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Development of an MR-only radiation therapy workflow

Skåne University Hospital developed a new workflow for MR-only radiation therapy treatments to improve accuracy of treatments and enable further increases in radiation dose to specific areas with more precision. The goal was to have an MR-only workflow that would avoid the introduction of image registration errors by using both MR and CT imaging. This work has been validated through numerous research studies conducted by Skåne University Hospital.

CT has historically been utilized as the primary imaging modality for tumor definition and dose calculation in radiation therapy treatment planning. However, MR provides better soft tissue contrast and resolution than CT and has been explored as an alternative for tumor definition and targeting.

Skåne University Hospital in Lund, Sweden, is a pioneer in the use of MR for radiation therapy planning. The radiation therapy department at Skåne University Hospital installed a Discovery™ MR750w, a 3.0T wide bore scanner, in 2013 to complement its two CT systems used for simulation. Eleven linear accelerators are used at Skåne University Hospital to treat between 6,000-7,000 cancer patients each year. Ten radiation oncologists, 22 radiation therapy physicists, one dedicated MR physicist and a large group of nurses, technologists and engineers staff the department.

By 2015, a team led by Lars E. Olsson, PhD, Professor of Medical Radiation Physics at Lund University and a physicist at Skåne University Hospital, and Adalsteinn Gunnlaugsson, MD, PhD, a Senior Consultant in the Department of Oncology at Skåne University Hospital, began researching the use of MR-only radiation therapy planning in prostate cancer patients.

"With MR, we are able to see the details of what we irradiate," says Dr. Gunnlaugsson. "This will better allow us to increase the dose to the tumor and spare normal tissues."

Even when using MR imaging to plan and direct cancer therapy, a CT examination is still acquired for dose calculations in the treatment planning system. However, the MR and CT need to be aligned as accurately as possible, since they are acquired on different systems and at different times. Unfortunately, the alignment will not be perfect, which leads to additional safety margins around the target that results in a higher radiation dose to healthy, non-cancerous tissues.

"This is a major source of error when working with two different imaging datasets," says Professor Olsson.

> "By eliminating the CT, we can reduce and save resources. Since we don't have to add the extra margin, we can actually reduce the dose to surrounding healthy tissue. This is the reason why we want to develop an MR-only workflow."
>
> *Professor Lars E. Olsson*

Christian Jamtheim Gustafsson, MSc

Skåne University Hospital
Lund, Sweden

Minna Lerner, MSc

Skåne University Hospital
Lund, Sweden

Discovery™ MR750w

PARAMETERS

	T2 PROPELLER	T2 frFSE	MERGE
TR (ms):	9151	15000	1000
TE (ms):	96	96	8
FOV (cm):	22	44.8	24
Slice thickness (mm):	2.8	2.5	2.8
Frequency:	352	640	164
Phase:		512	164
NEX:	2.1	1	2
Scan time (min):			5:36

Download the Gold Atlas dataset at: tiny.cc/sps193

To implement an MR-only treatment planning workflow, the team together with Spectronic Medical AB (Helsingborg, Sweden) developed a method for generating Hounsfield Units (HU) maps from synthetic CT (sCT) images derived from the MR data. The Statistical Decomposition Algorithm (SDA) automatically generates sCT images from MR imaging data by using automatic tissue classifications and a model trained with multi-modal template materials. The team validated the accuracy of the SDA model against conventional CT Sim data and found it to be highly accurate.[1]

As part of this effort and in collaboration with other Swedish academic hospitals, Skåne University Hospital participates in Gentle Radiotherapy, a national program funded by the Swedish Innovation Agency, VINNOVA, and associated hospitals. The long-term goal of Gentle Radiotherapy is to create a large-scale national world-class platform for cancer treatment, including the development of a fully integrated MR-only workflow for radiotherapy. The project has also published the Gold Atlas data, a complete dataset of the male pelvic region that is a source for training and validation of segmentation algorithms and methods to convert MR to sCT.[2]

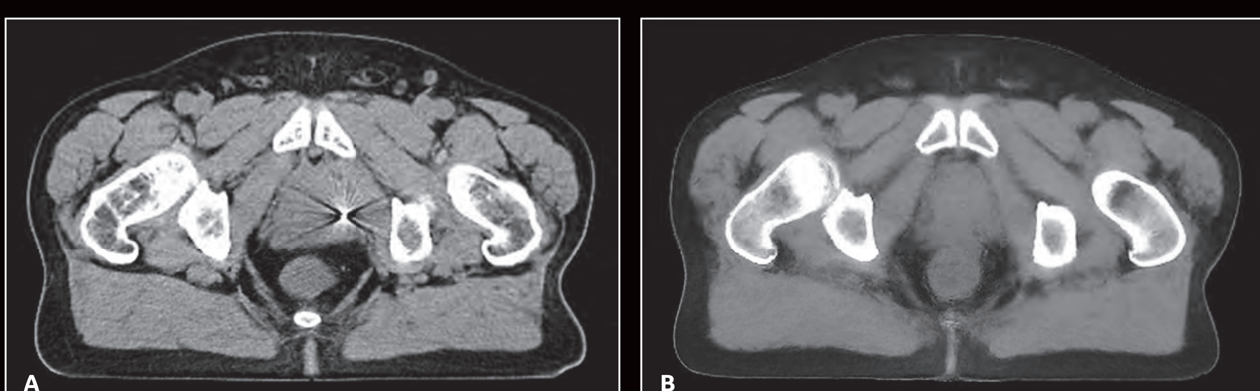

Figure 1. Comparison of (A) CT and (B) sCT images.

Images copyrighted by Christian Jamtheim Gustafsson, Lund University, reprinted with permission. Thesis: MRI-Only Radiotherapy of Prostate Cancer - Development and evaluation of methods to assess fiducial marker detection, geometric accuracy and dosimetric integrity ISBN: 978-91-7619-775-2.

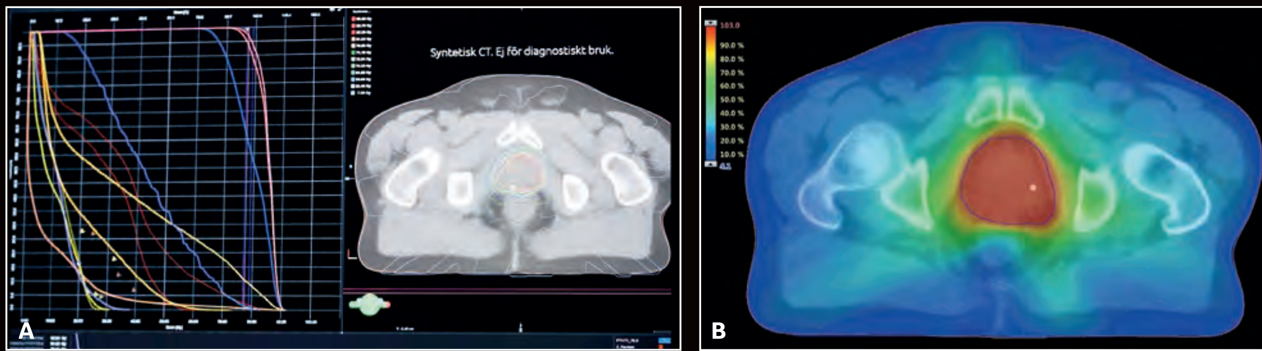

Figure 2. (A) sCT is used for dose calculations in treatment planning system; (B) sCT with dose distributions.

Image 2B copyrighted by Christian Jamtheim Gustafsson, Lund University, reprinted with permission. Thesis: MRI-Only Radiotherapy of Prostate Cancer – Development and evaluation of methods to assess fiducial marker detection, geometric accuracy and dosimetric integrity ISBN: 978-91-7619-775-2.

Results of a multi-center study validating MR-only prostate planning using synthetic CT images reported minimal differences between CT and sCT.[3] The MR-Only Prostate External Radiotherapy (MR-OPERA) study found that an atlas-based sCT generation software, MriPlanner (Spectronic Medical), provided dosimetrically accurate data compared to CT Sim and delivered a robust workflow that required only minor changes in the clinical routine.[3] The study included scanners from two different manufacturers at two field strengths. This important study, performed by PhD student Emilia Persson at Skåne University Hospital, was a significant step forward in the development of an MR-only workflow.

Another research study led by several leading hospitals in Finland with contributions from institutions in Australia, the Netherlands, Denmark and Skåne University Hospital also examined the use of an intensity-based method to generate sCT images from standard T2-weighted images of the pelvis. The authors found this method produced clinically acceptable dose calculation results across 35 prostate cancer patients.[4] As with MR-OPERA, this study was conducted on different MR systems to demonstrate reliability across scanners and sequences.

"In many cases, our research is different when it comes to MR-only radiation therapy," says Professor Olsson. "While many sites are developing different techniques, most will not treat the patient with MR-only imaging. When we started this initiative, our goal was to implement MR-only treatment in the clinic similarly to conventional, CT-based treatments."

A body of research

To accomplish the goal of MR-only guided radiation therapy planning, additional methods and tools were developed by the Skåne University Hospital team. This includes an automatic registration-free method for identifying implanted gold fiducial markers using multi-echo gradient echo imaging[5], development and evaluation of a technique to quantify the dosimetric effects of MR system specific distortions for sCT images[6] and a dose quality assurance procedure for sCT using the cone beam CT (CBCT) imaging device on the linear accelerator.[7]

In MR, T2-weighted spin echo images depict gold fiducial markers as a small signal void similar to calcifications and post-biopsy fibrosis. While the use of multi-echo gradient echo imaging was shown to be feasible and reliable for identifying gold fiducial markers[5], the team also wanted to develop a quality assurance method for this process. The goal is to have an MR-only workflow that would not change the radiation therapy workflow and to avoid the introduction of image registration errors by using both MR and CT imaging. The team addressed this issue using the

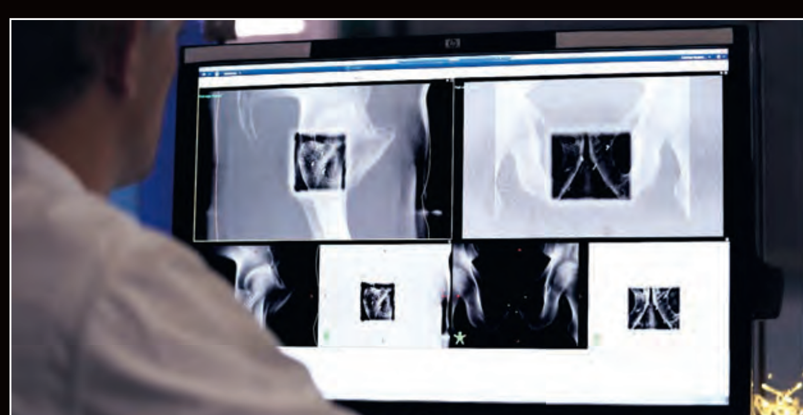

Figure 3. Onboard kV X-ray images are used to verify the patient position. The fiducial markers seen in the kV images match very well to the markers seen in the digitally reconstructed radiograph generated from the sCT. If the patient does not have fiducial marker implants, bony structures can be used for position verification.

Image courtesy of Gentle Radiotherapy.

C-arm X-ray images that are acquired during implantation of the gold fiducial markers to confirm fiducial placement. Their study demonstrated that this approach was feasible and using the method as described in the paper would completely remove the need for CT imaging, as well as potentially provide an MRI-independent redundant method for gold fiducial marker verification.[8]

The issue of geometric accuracy was also a key concern with the use of MR-only radiation therapy and a potential obstacle to its use. So, it was a logical starting point to investigate whether distortions from a non-linear gradient in an MR system were a true problem or could be resolved.

"As shown in our paper, this is a very manageable issue," explains Christian Jamtheim Gustafsson, MSc, a medical physicist at Skåne University Hospital. "By using 3D distortion correction and managing patient magnetic susceptibility differences by increasing the receiver bandwidth, we can address this. We've shown this in our papers, as well as in studies from other sites, that this really is not a problem." Gustafsson is in the process of submitting his PhD thesis, and at the end of May he will be the first student in the group to get his PhD exam from the results of this project.

The acquisition of a large field-of-view (FOV) to cover the entire pelvic region for sCT generation could lead to geometric distortions, since the non-linear gradient effect enhances as the radius from the isocenter increases. However, when 3D distortion correction and high acquisition bandwidths were used for images with large FOVs, no clinically relevant dose difference or structure deformation was detected.[6]

"Our initial investigation in the use of MR-only for brain cancers demonstrates the same answer, that all distortion sources are very manageable."

Christian Jamtheim Gustafsson

Figure 4. Each patient is imaged in the treatment position with patient positioning devices.

Image courtesy of Gentle Radiotherapy.

Although the MR-OPERA study validated the generation of sCT images for the male pelvis from T2-weighted images using MriPlanner, an independent QA evaluation of the sCT data was desired prior to the first treatment. Armed with published data that demonstrated the use of CBCT for patient-specific QA in brain radiotherapy[9], the team explored the use of CBCT for QA of sCT data for prostate cancer patients and to verify the sCT data in regard to absorbed dose.

Not only was the CBCT system shown to be equivalent to CT in terms of HU, but dose calculations based on CT and sCT data sets had absorbed dose differences that were within clinically acceptable criteria. Further, errors introduced into the sCT data to test the QA capabilities were detected in the study.[7]

From bench to bedside

From the start, the motivation behind the research conducted by Skåne University Hospital has been to validate the use of MR imaging in radiation therapy and to rely only on MR imaging data in an effort to improve the accuracy of treatment delivery. This effort has been consolidated into a guide published by Gentle Radiotherapy.

"Improving the accuracy of our treatment delivery will allow us in the future to further increase dose to specific areas with much more precision."

Dr. Adalsteinn Gunnlaugsson

Increasing radiation dose to the target is becoming more common in cancer treatments, such as intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT), to improve tumor control and lower the risk of recurrence. Another treatment technique is stereotactic body radiation therapy (SBRT), which delivers very precise, high doses of radiation to cancer cells while minimizing radiation exposure to surrounding healthy cells.

GENTLE RADIOTHERAPY

View the Gentle Radiotherapy Methodology guide: tiny.cc/sps192

Although the department at Skåne University Hospital is not yet using SBRT in the MR-only prostate workflow, Dr. Gunnlaugsson anticipates the development of the MR-only treatment platform will enable SBRT treatments in the future. Even for brachytherapy, another treatment for prostate cancer that involves the placement of radioactive implants directly into the tissue, there is an expectation that an MR-only workflow could be beneficial.

"We also aspire to have gynecological brachytherapy treatments move to MR-only and remove the CT imaging," adds Gustafsson. "Most of the target delineation today is performed on T2-weighted MR imaging, and we are in the process of optimizing and evaluating the Cube sequences for brachytherapy of the cervix."

T2-weighted images are predominantly used for target delineation in the prostate and, more recently, in the brain as well. Skåne University Hospital also uses 3D T1 Cube sequences in brain imaging to visualize contrast uptake in the tumors and PROPELLER to compensate for motion. Currently, most of the clinical research has been on morphological rather than functional MR sequences. However, FOCUS, a DWI sequence, is applied in both the prostate and brain using b-values of 200 and 800.

Other protocol adaptations may occur for patients who require the use of vacuum pillows for patient positioning and fixation. "The implication of the use of vacuum pillows or other patient immobilization devices is that the coil may be placed further from the patient's anatomy, which in turn decreases SNR," Gustafsson says.

Recently, the last patient was enrolled in the Skåne University Hospital study of prostate patients treated with the MR-only radiation therapy planning process.

"Because we tested and validated all aspects of the MR workflow, we were comfortable treating patients in a clinical study," adds Dr. Gunnlaugsson.

The team is also working to apply the MR-only radiation therapy workflow to brain cancer, including glioma and metastases. For sCT image generation in the brain, IDEAL is utilized to provide water-only, fat-only, out-of-phase and in-phase images. This arm of the research project began in Autumn 2018.

"We are in the validation process and setting up the workflow to implement the same process in the clinic for treatment," says Minna Lerner, a research PhD student in the department. While much of the workflow developed for prostate cancer can be applied to brain cancers, there are additional considerations that need to be taken into account.

Figure 5. T2-weighted images are predominantly used for target delineation in the prostate. (A-D) PROPELLER is used to compensate for motion.

Images copyrighted by Christian Jamtheim Gustafsson, Lund University, reprinted with permission. Thesis: MRI-Only Radiotherapy of Prostate Cancer - Development and evaluation of methods to assess fiducial marker detection, geometric accuracy and dosimetric integrity ISBN: 978-91-7619-775-2.

Figure 6. MR images are used in the treatment planning system for target delineation and dose distributions.

Image courtesy of Gentle Radiotherapy.

For example, each patient is imaged in the treatment position with their head in an immobilization device. The distance from the back of the head to the MR table must be calculated for dose planning on each patient. Previously, this information would have been manually measured. Lerner is using an ASTM-compatible zero echo time (ZTE) MR imaging technique to calculate the distance.

A key consideration throughout the development of the MR-only radiation therapy planning environment is to replicate the current workflow.

"Once we have all these tools and techniques in place for MR-based radiation therapy, it is not very different from a CT-based workflow. We can use the same clinical criteria as we would in a conventional workflow and we have found the MR-only workflow performs equally well if creating an IMRT or VMAT plan."

Christian Jamtheim Gustafsson

In addition to using the knowledge gained from MR-only radiation therapy of the prostate in brain cancer cases, the team at Skåne University Hospital is also focused on education. The institution hosted a 2018 GE meeting and two international workshops on the use of MR for radiation therapy planning.

"That is one of our strengths—with the university, we are able to set up educational events around this new technique," adds Professor Olsson.

From education to sharing protocols to describing the new MR-only workflow, Skåne University Hospital is committed to sharing their insight and expertise in the development of MR-only radiation therapy. While the challenge of being one of the first institutions in the world to embrace an MR-only radiation therapy workflow led to the development of new techniques, tools and processes, the team is eager to continue demonstrating the value of MR imaging in cancer treatment planning. S

Watch videos produced by Gentle Radiotherapy on the concept behind and implementation of MR-only radiation therapy. http://gentleradiotherapy.se

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Thirty-minute PET/MR exam for pediatric cancer patients

By Jing Qi, MD, Assistant Professor, and Nghia (Jack) Vo, MD, Chief of Pediatric Radiology, Medical College of Wisconsin

Clinicians at the Children's Hospital of Wisconsin have developed a 30-minute PET/MR exam for evaluating pediatric cancer patients. After comparing the results of PET/MR to PET/CT in many patients across different disease types and conditions, the facility has successfully converted all PET/CT studies to PET/MR. In several instances, PET and MR are discordant, helping improve the diagnosis.

The Medical College of Wisconsin (MCW) is an academic partner of the Children's Hospital of Wisconsin, a top-ranked pediatric hospital and one of the nation's busiest. While PET/CT had been utilized for the diagnosis and staging of cancer patients, our facility acquired a SIGNA™ PET/MR in late 2017 and scanned our first patients in February 2018. The PET/MR is clinically utilized for 75% of our oncology cases, primarily sarcoma and lymphoma, and 25% for brain cases, including seizures and tumors.

A 2014 study published in *Radiology* of 20 whole-body PET/CT and PET/MR exams in 18 pediatric patients reported that PET/MR demonstrated equivalent lesion detection rates in pediatric oncology cases compared to PET/CT. The study indicated that MR had a higher sensitivity than PET or PET/CT for solid organs and bone lesions and in several cases provided additional diagnostic information in areas of soft tissue.[1] Further, the lack of ionizing radiation exposure from CT makes PET/MR an attractive alternative, as many children will receive multiple imaging exams during their course of treatment.[1]

Additionally, a review article on FDG PET/MR imaging for malignancies noted that the additional morphologic and functional information provided by MR may help further characterize FDG uptake in a suspicious lesion.[2] Another study reported that additional findings from PET/MR impacted patient clinical management in nearly 18% of cases.[3]

The disadvantage of PET/MR compared to PET/CT is the longer scan times for MR versus CT. We addressed this issue by taking PET as the time-limiting factor and tailoring our MR sequences to fit into the PET acquisition times. Based on three-minute per bed positions, we acquire a 15-second MRAC to generate an AC Map, a 40-second Axial T1 LAVA Flex sequence for anatomic registration and then a two-minute Axial T2 frFSE Flex for pathology survey. The T2 frFSE Flex generates both FatSat and non-FatSat images, while the T1 LAVA is acquired in 3D so we can reformat the data into Coronal and Sagittal views for image registration with PET.

Further, the ability to provide concurrent MR with PET in the same setting under one sedation is best for the pediatric patient and their parents. The oncologists are also pleased with the information we are able to provide in a three-minute PET/MR per bed exam, as demonstrated in the following patient cases. We are continuing to evaluate the efficacy of this short PET/MR exam in the long-term management of lymphoma and sarcoma, as well as investigate the use of PET/MR in pheochromocytoma and possible medulloblastoma patients.

With the implementation of PET/MR, we have successfully converted PET/CT imaging studies for our pediatric cancer patients to PET/MR.

SIGNA™ PET/MR

PARAMETERS

	MRAC	*Axial LAVA Flex*	*Axial T2 frFSE Flex*
TR (ms):	4	3.8	3000 – 3600 variable
TE (ms):	1.7	1.7	
FOV (cm):	50	48	48
Slice thickness (mm):	5.2	3	5
Frequency:	256	224	300
Phase:	128	256	256
NEX:	0.7	0.7	3
Scan time (min):	0:15 (sec.)	0:17 (sec.)	1:43
Options / other (b-value, no-phase wrap, etc.):	EDR, Zip2, Flex	SATS: S/I, Zip2, EDR, Flex, ARC	FC/s. SATS: S/I, ARC, EDR, TRF, Flex

Case 1

A 21-year-old Hodgkin's lymphoma patient originally staged with PET/CT. Patient was scanned using PET/MR on the second day of clinical service. Patient was scanned with seven bed positions, three minutes each bed position, for a total scan time of 21 minutes.

Results: Complete response with uptake equivalent to the blood pool. Tumor is dark on T2-weighted sequence, suggesting fibrotic changes or scar tissue. Patient remained PET negative at completion of the chemotherapy.

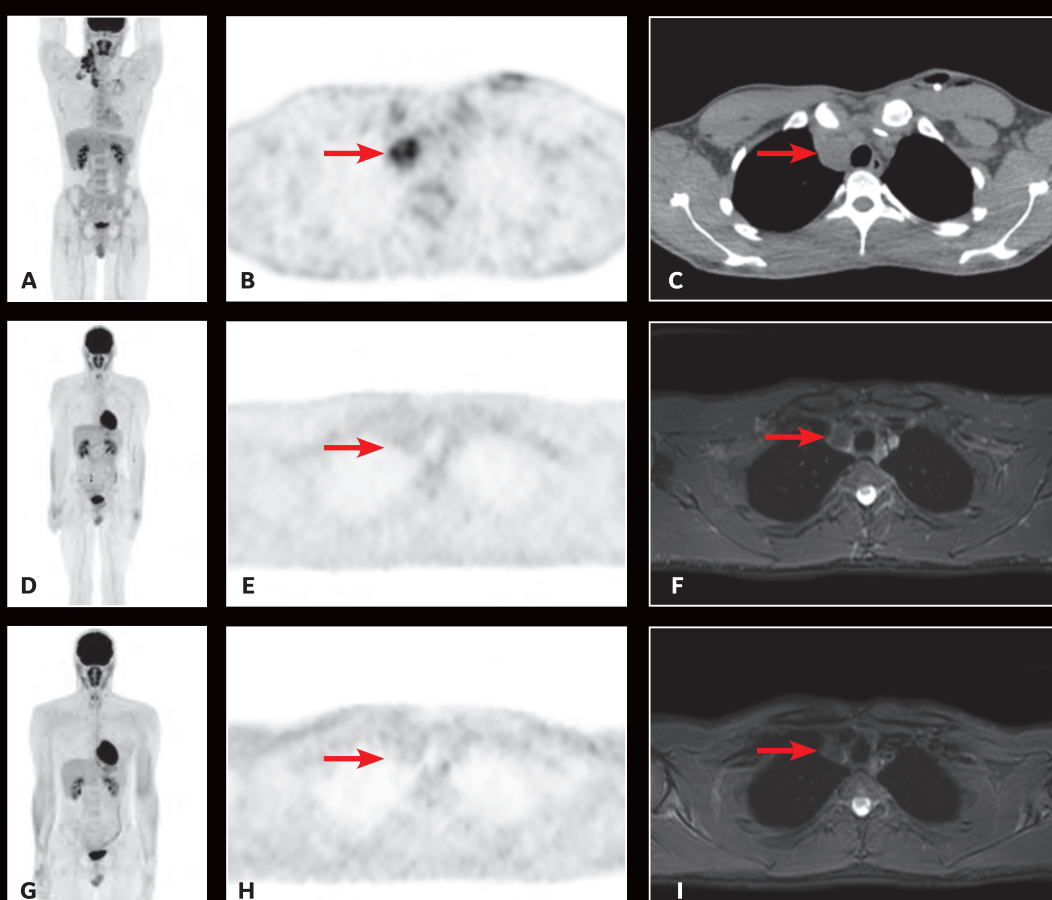


Figure 1. Case 1. A 21-year-old patient with Hodgkin's lymphoma, restaged with PET/MR. (A-C) Initial staging PET/CT; (D-F) Interim PET/MR; and (G-I) restaging PET/MR.

Case 2

A 16-year-old female with desmoplastic small round cell tumor was the first patient to undergo only PET/MR (no PET/CT). Patient had widespread disease throughout the abdomen, including a pelvic lesion and soft tissue mass coating the diaphragm. The patient had debulking surgery and was referred for restaging. Unfortunately, due to her size (200 lbs., 5 feet 4 inches and BMI 32) the bellow belt for breathing/gating kept catching on the bore and the scan would abort. We eventually decided to not use respiratory gating for the study. PET/MR images were acquired two hours after injection, yet despite the low photon count we were able to acquire good diagnostic-quality images.

Results: A suspicious residual, hyperdense lesion in the pelvis seen on CT was well characterized on MR, low intensity on both T1 and T2-weighted sequences and without FDG uptake, most consistent with a complex fluid collection (Figure 2).

The diaphragm lesion is well seen on the T2 FatSat image and the Sagittal reformat (Figure 2C, 2D) even with the free-breathing sequence and it correlates with abnormally increased FDG uptake. Findings are consistent with residual disease.

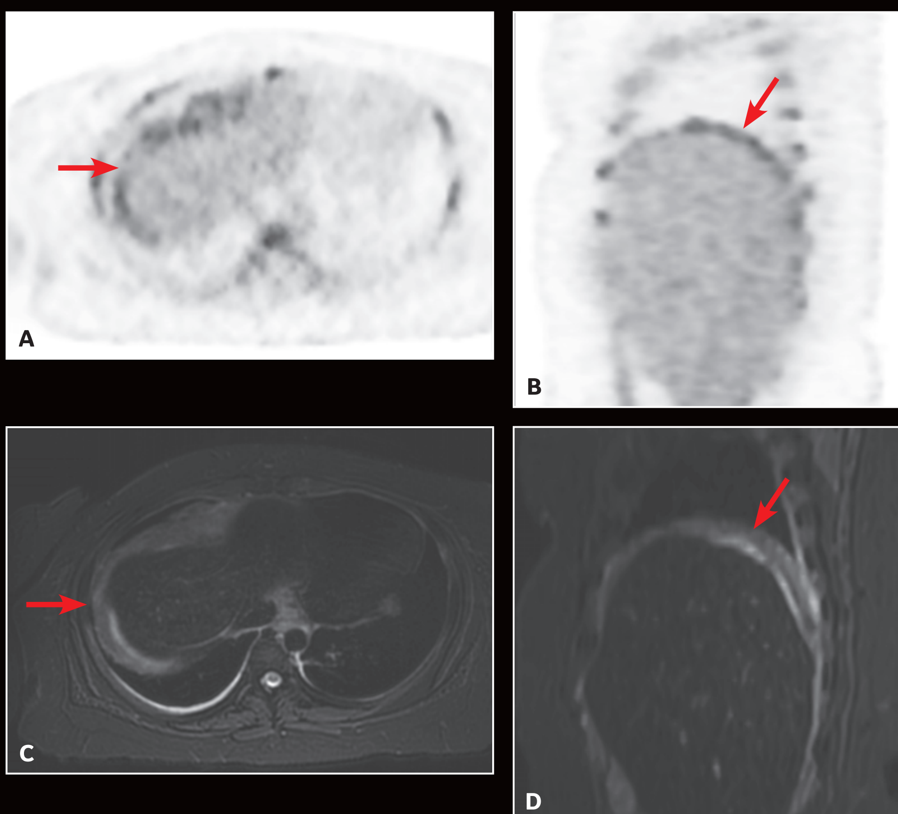


Figure 2. Case 2. A 16-year-old patient with residual disease over the pleural surface of the diaphragm (red arrows). Despite imaging the patient two hours after FDG, good diagnostic quality images were still acquired on PET. The hyperdense residual lesion is well characterized by MR. (A, B) PET with (C, D) corresponding T2 FatSat MR slices.

Case 3

A newly diagnosed 13-year-old patient with Ewing's sarcoma was referred to PET/MR to confirm initial diagnosis on a dedicated MR system. In this case, the quality of the T2 frFSE Flex sequence captured on the PET/MR was similar to the dedicated MR. There are two small foci next to the spine that correspond with lesions in the deep fascia of the spinal muscle and the other in a paraaortic lymph node. In retrospect, those can be seen on the diagnostic MR performed five days prior (Figure 3C, 3D).

Results: Patient had a tumor in the left spinal muscle with high-grade FDG uptake at time of staging. Adjuvant therapy shrunk the primary tumor and two hot spots (Figure 4), leading to negative surgical margins.

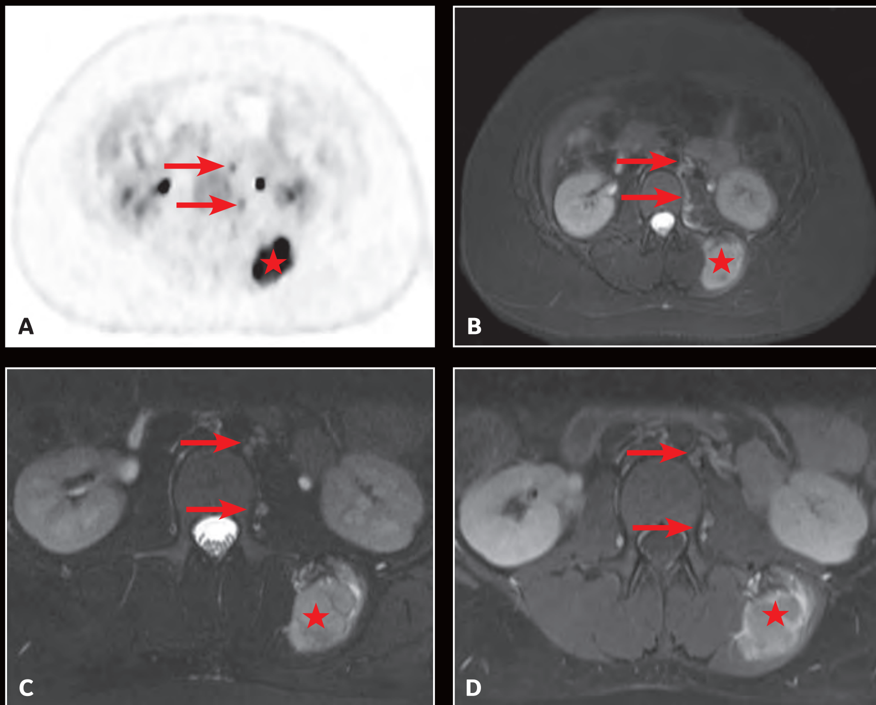


Figure 3. Case 3. A 13-year-old female with Ewing's sarcoma. (A) PET image from PET/MR exam; (B) T2 frFSE Flex FatSat from PET/MR exam; and initial diagnostic MR exam (C) T2 frFSE Flex FatSat and (D) T1 contrast enhanced. The quality of the (B) T2 frFSE Flex FatSat on PET/MR is the same quality as the (C) T2 frFSE Flex FatSat on the dedicated MR.

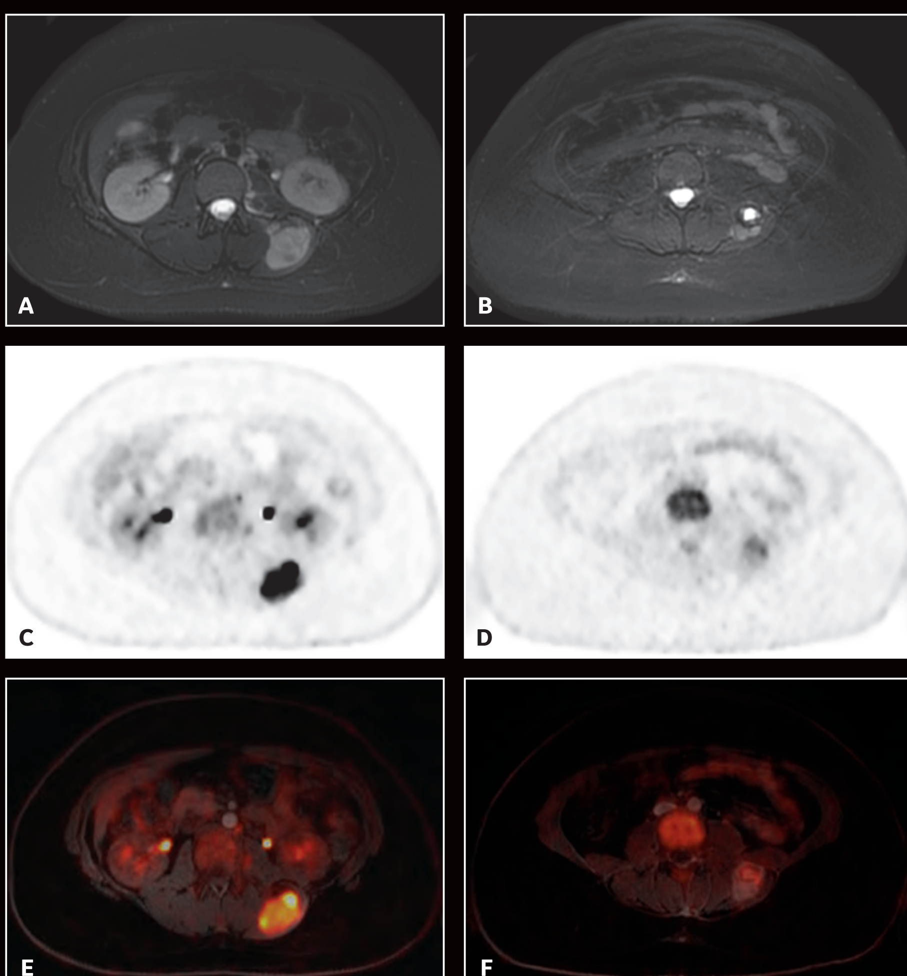
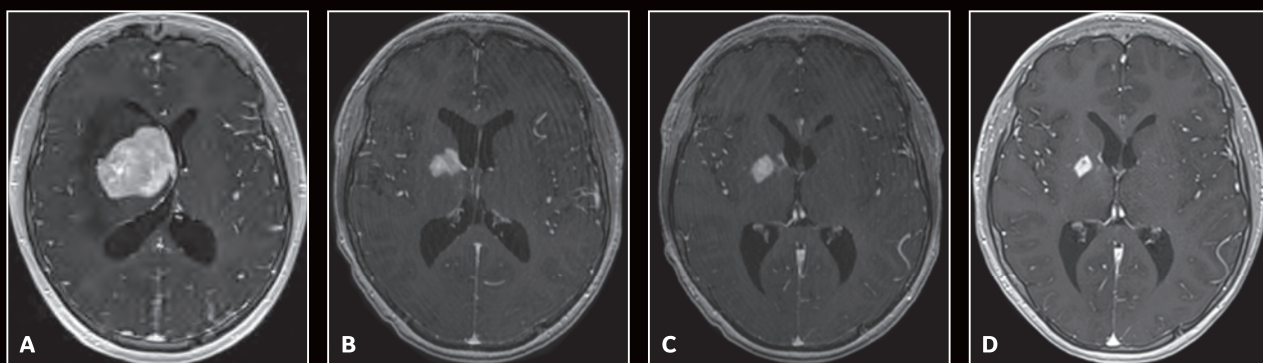


Figure 4. Case 3. Adjuvant therapy shrunk the primary tumor and two hot spots leading to negative surgical margins. (A, C, E) PET/MR exam prior to treatment and (B, D, F) PET/MR two- and one-half months after start of treatment.

Case 4

A 16-year-old patient with large B cell lymphoma who relapsed with lesions in the brain and underwent salvage chemotherapy. Monthly dedicated MR imaging demonstrated a continual decrease of the lesions in the first two months of therapy that lessened near the end of the treatment. Stem cell transplant was planned; however, the patient prognosis is better if they have complete remission. We proposed PET/MR to help determine if the lesions were scar tissue or viable tumors, and whether the patient was in complete remission. The PET study was acquired concurrently with a dedicated MR study.

Results: Uptake in the right basal ganglia corresponds with enhancement on the MR, suggestive of a residual lesion. Patient underwent another round of chemotherapy prior to stem cell transplant.



3/30/18 4/23/18 5/15/18 6/19/18

Figure 5. Case 4. A 16-year-old with large B cell lymphoma, who relapsed with lesions in the brain. MR images acquired with PET/MR.

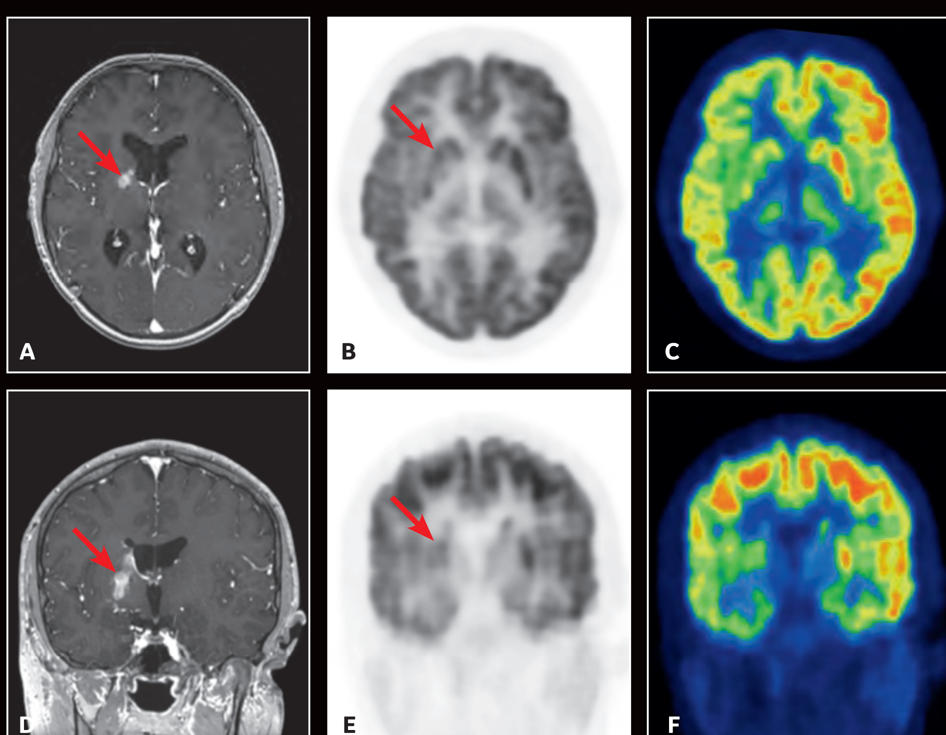


Figure 6. Case 4. Same patient. Uptake in the right basal ganglia (B, E, red arrows) corresponds with enhancement on the MR (A, D, red arrows), suggestive of a residual lesion. (A, D) MR; (B, E) PET; and (C, F) fused PET/MR.

Case 5

A 12-year-old with undifferentiated sarcoma, widespread disease in the chest, abdomen, pelvis and the thigh muscles. There appears to be foci in the corpus callosum.

Results: There are discordant findings between MR and PET in the post-treatment imaging: there is an increase in the lesion size on the MR image and a decrease in activity in the PET image. There appears to be a progression of disease and this patient will be followed using PET/MR.

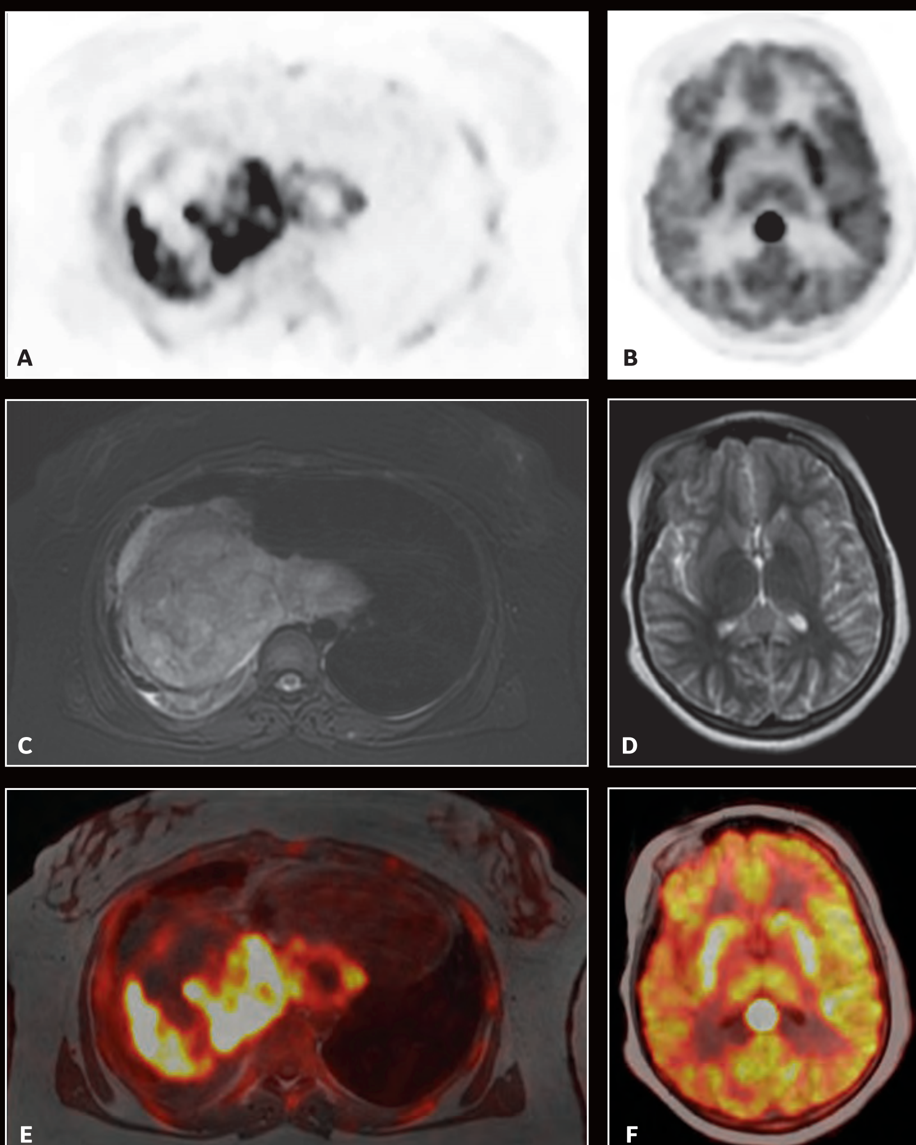


Figure 7. Case 5. Initial PET/MR exam. A 12-year-old with undifferentiated sarcoma and widespread disease. (A, B) PET; (C, D) MR; and (E, F) fused PET/MR.

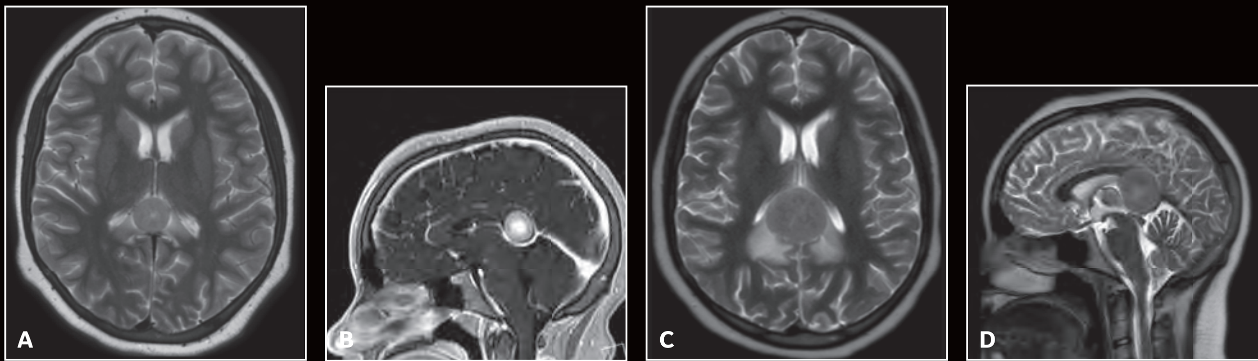


Figure 8. Case 5. After two cycles of chemotherapy, MR imaging depicted an increase in brain lesion size. (A-D) MR images acquired on PET/MR.

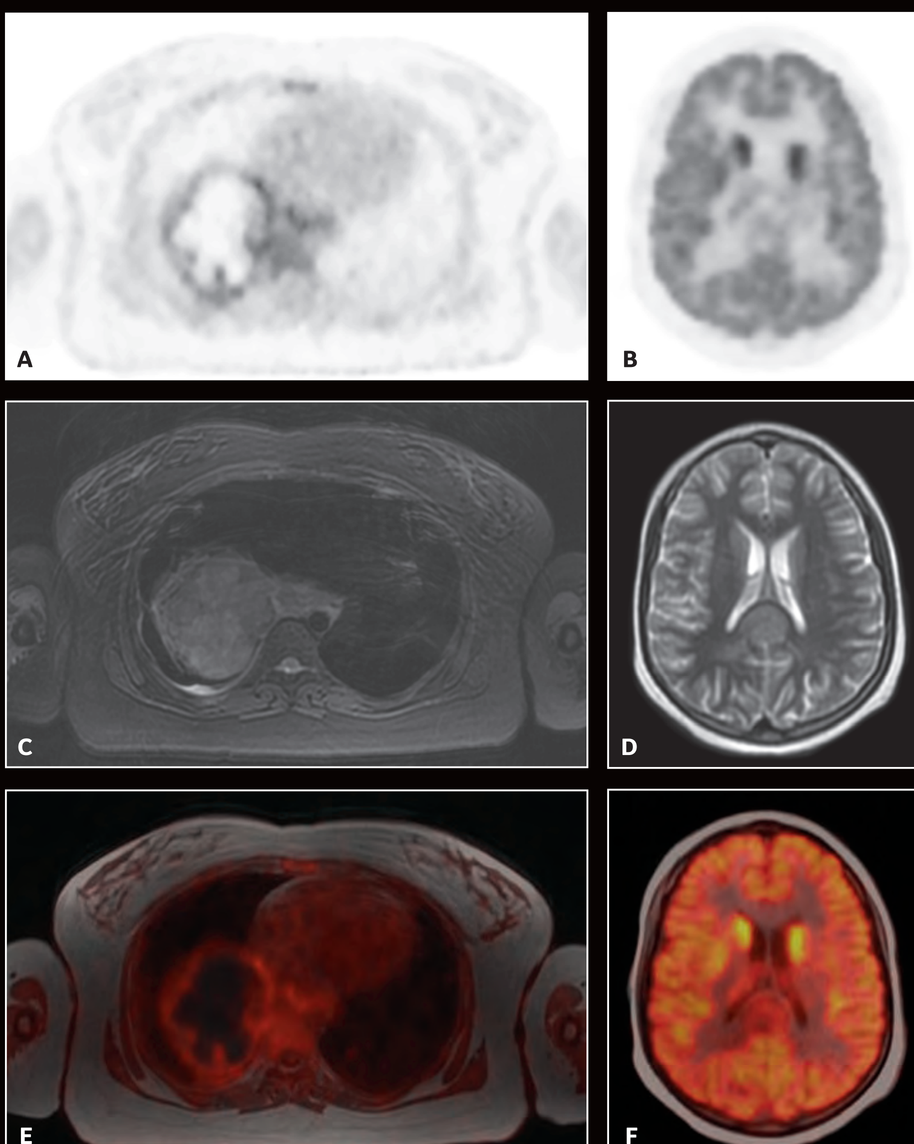


Figure 9. Case 5. Discordant findings between PET and MR in post-treatment PET/MR exam. (A, B) PET; (C, D) MR; and (E, F) fused PET/MR.

Case 6

A 9-year-old patient who underwent a liver, pancreas and small bowel transplant at age 2. Patient has abdominal pain, fever and vomiting. Initially, a white blood cell scan using nuclear medicine was ordered; however, we recommended PET/MR due to its higher spatial and contrast resolution. We utilized PET/MR to look for foci of infection, inflammation or organ rejection, as well as provide sites/ targets for biopsy.

Results: There are two foci in the abdomen with FDG uptake: one in the right quadrant that correlates with the small bowel and the other next to the surgical anastomosis in distal small bowel. With the PET/MR exam, we were able to provide two areas for biopsy. S

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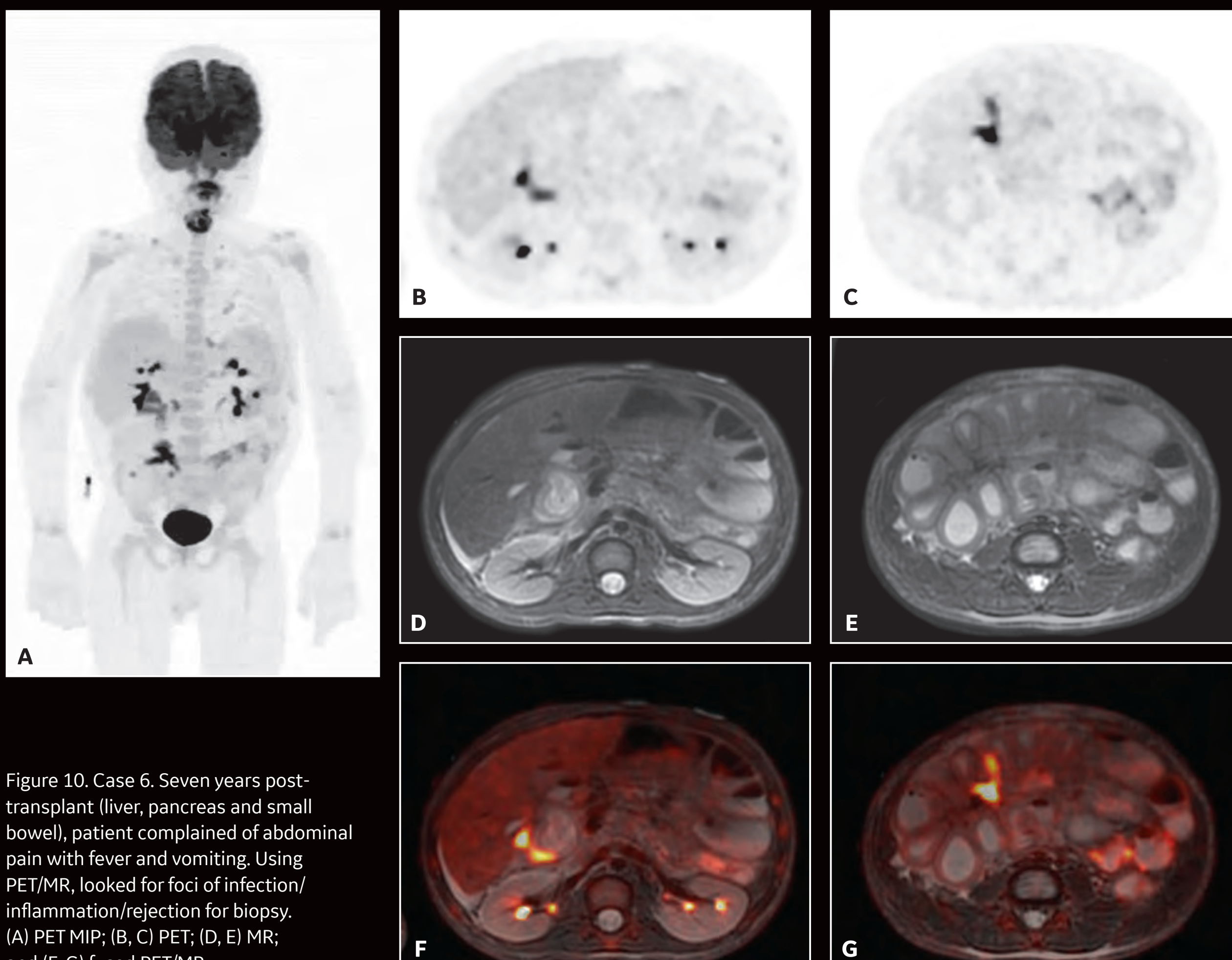
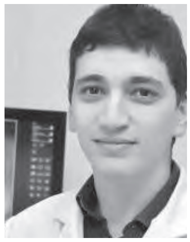


Figure 10. Case 6. Seven years post-transplant (liver, pancreas and small bowel), patient complained of abdominal pain with fever and vomiting. Using PET/MR, looked for foci of infection/ inflammation/rejection for biopsy. (A) PET MIP; (B, C) PET; (D, E) MR; and (F, G) fused PET/MR.



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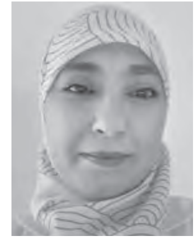

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Whole-body diffusion for evaluation of metastatic lesions

By Abdelhamid Derriche, MD, site radiologist, and Orkia Ferdagha, MR technologist, PRIISM, EHP Kara

Cancer patients are often referred for whole-body imaging to evaluate the presence of secondary or metastatic lesions, which can change the course of patient treatment. In our institution, whole-body diffusion MR is our preferred modality for this type of study.

Diffusion-weighted imaging (DWI) on MR has shown excellent sensitivity (82%) and specificity (97%) compared to PET/CT (sensitivity of 72% and specificity of 92%) in whole-body imaging in melanoma metastases.[1] Additionally, DWI MR has been shown to be the most accurate for detecting metastases in the bone, liver, subcutaneous and intra-peritoneal sites compared to PET/CT.[1]

However, non-optimal DWI MR acquisitions can produce scintigraphy-like images that may produce false positive results. Combining DWI MR with an inversion time technique can help overcome this issue by allowing for a better suppression of fat signal, which helps suppress background body signal. Further, utilizing an MR system that has strong magnet homogeneity allows for the acquisition of large field-of-view (FOV) images and helps reduce distortions in areas of off-center imaging, such as the extremities. DWI STIR with a “3-in-1” technique provides an excellent compromise between acquisition time and signal-to-noise ratio (SNR), allowing acquisition of thin slices that may help further enhance sensitivity of the DWI sequence.

Patient history

A 75-year-old female with known melanoma was referred for whole-body DWI MR for evaluation of suspected metastatic (secondary) lesions on her extremities. Post-contrast whole-body MR with LAVA Flex was also used to evaluate areas with suspicious contrast uptake.

MR findings

- Important effusion on the glenohumeral joint of the right shoulder, to be investigated
- Several bilateral swollen axillary lymph nodes, predominant in number and size at the right axillary region
- Lesion located on the proximal metaphysis of the ulna of the left arm and suspected to be metastatic, measuring 13 mm from its long axis, hyperintense in diffusion, hyperintense in STIR and gadolinium-enhanced on post-contrast T1 sequence
- Second suspicious lesion with similar aspect, measuring 9 mm and located on the distal diaphysis of the radius of the right arm
- Lesion on the left iliac joint, measuring 6 mm, hyperintense in diffusion, with no aspects on the other sequences
- Small nodule of 15 mm situated on the soft tissues of the right thigh, at the inferior part located within the posterior muscular compartment, hyperintense in diffusion.

SIGNA™ Explorer

PARAMETERS

	Coronal LAVA Flex	*Coronal STIR*	*Axial Diffusion STIR*	*Coronal LAVA Flex post contrast*
TR (ms):	5.8 (2nd station 5.7)	8000 (2nd station 2225)	6811	5.8
TE (ms):	3.1 (minimum TE)	33	60 (minimum TE)	3.1
FOV (cm):	48	48	48	48
Slice thickness (mm):	2.6	8	3	2.6
Frequency:	192	320	110	192 (170)
Phase:	160	224 (160)	110	160 (150)
NEX:	1	1	b0 = 3, b600 = 12	1
b-value:			0, 600	
Scan time (min):	0:42 (sec.)	2:00	1:49	0:42 (sec.)
Options / other:	2nd station 0:21 sec. for breath-hold	2nd station 1:30 min. with 0:18 sec. breath-hold	20 stations	2nd station 0:21 sec. for breath-hold

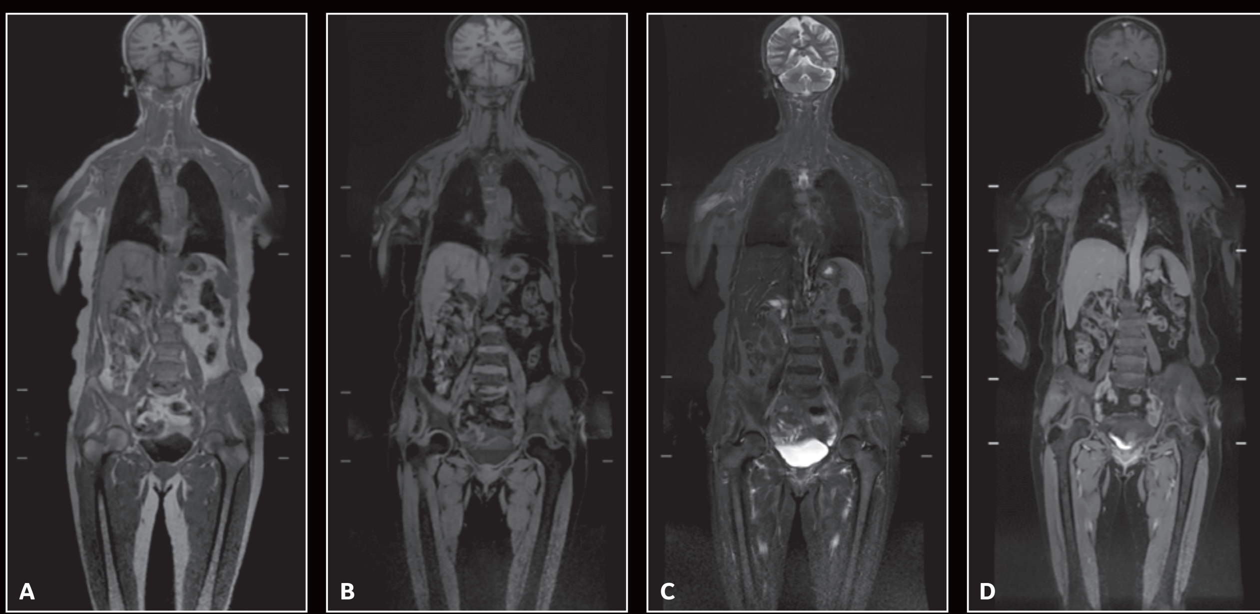

Figure 1. Whole-body MR imaging with approximately 120 cm coverage. (A-B) Coronal in-phase and water LAVA Flex; 2.5 x 3 x 2.6 mm, 3 stations, 1:45 min.; (C) Coronal STIR, 1.5 x 2.1 x 8 mm, 3 stations, 5:30 min.; and (D) Coronal water LAVA Flex, post contrast, 2.5 x 3 x 2.6 mm, 3 stations, 1:45 min.

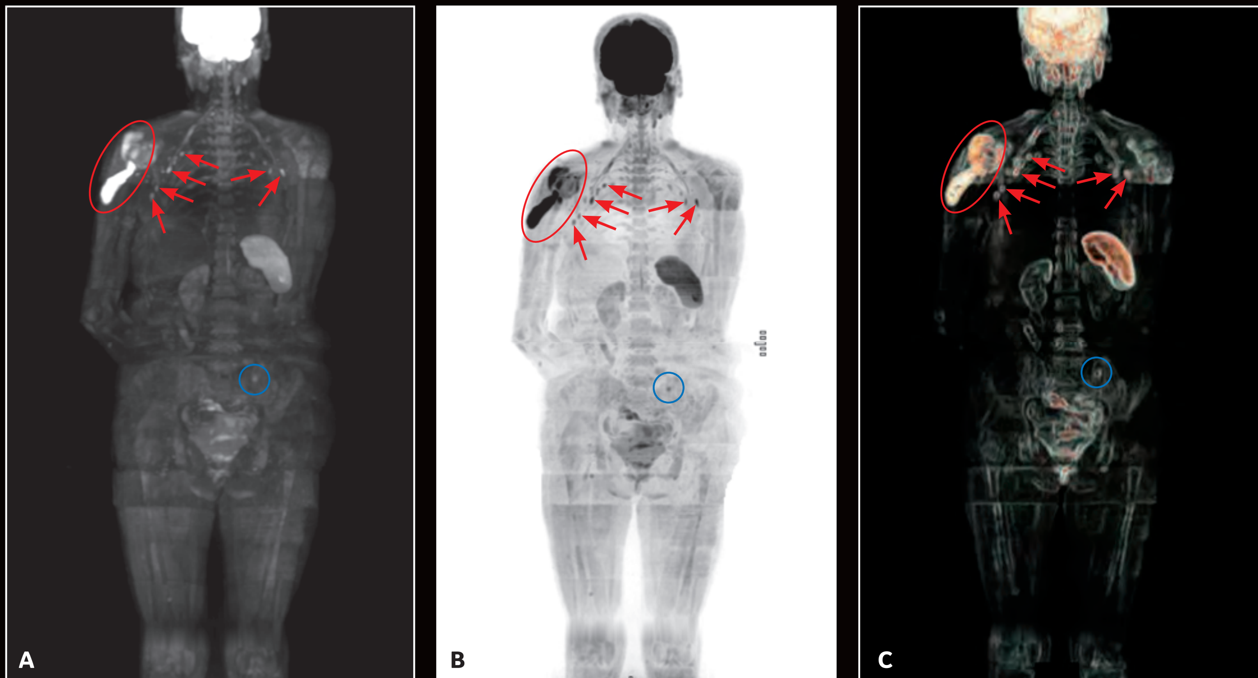

Figure 2. Whole-body MR imaging with approximately 120 cm coverage. Binded Axial diffusion STIR 3-in-1, b600, 4.4 x 4.4 x 3 mm, 20 stations, 36:20 min. (A-B) MIP projections; and (C) volume rendered image. Red circle depicts the effusion on the glenohumeral joint of the right shoulder. Red arrows show the bilateral swollen axillary lymph nodes. Blue circle denotes the lesion on the left iliac joint.

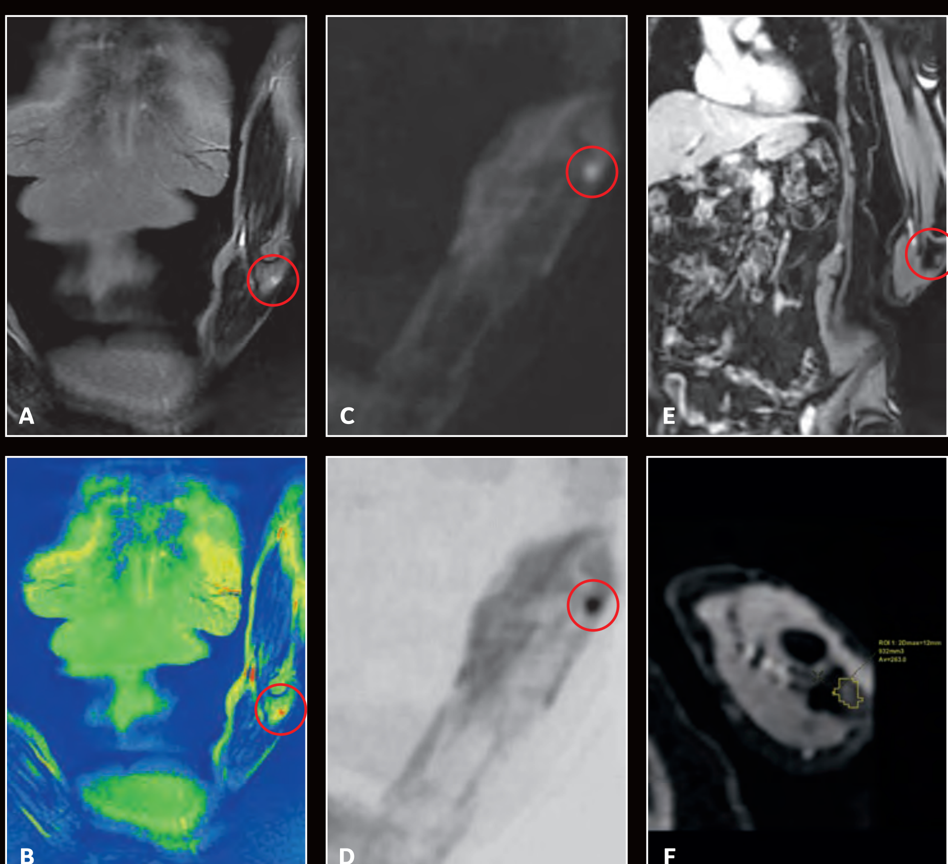

Figure 3. (A) Coronal STIR, 1.5 x 2.1 x 8 mm; (B) same image with color map; (C-D) diffusion STIR 3-in-1 b600, 4.4 x 4.4 x 3 mm; and (E-F) Coronal water LAVA Flex post contrast, 2.5 x 3 x 2.6 mm and Axial MPR. Lesion located on the proximal metaphysis of the ulna of the left arm (red circle), suspected to be metastatic.

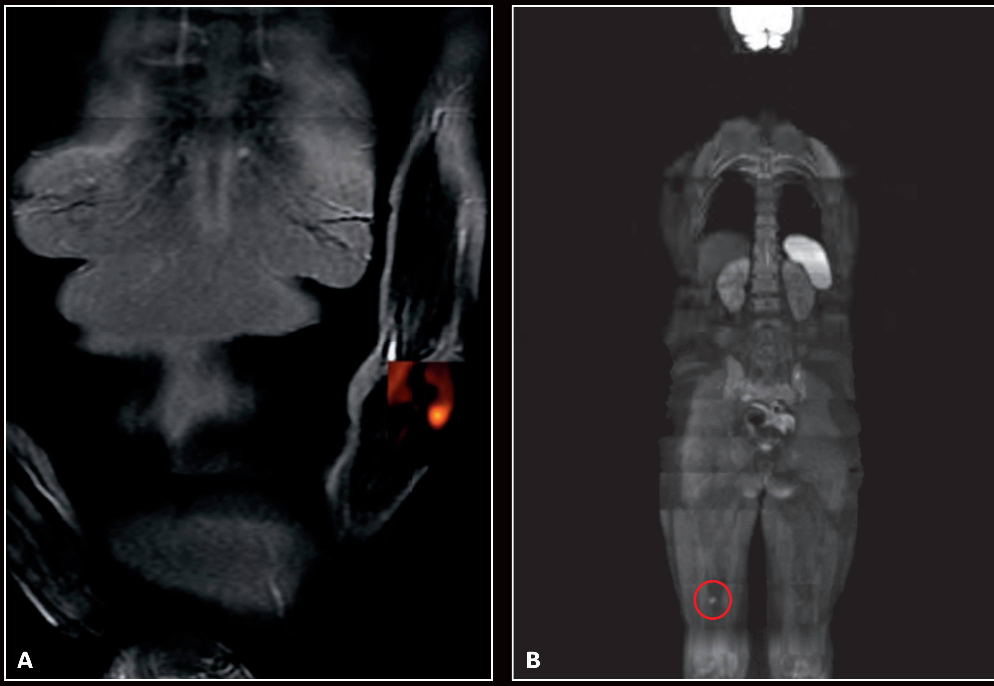

Figure 4. (A) Fusion STIR + diffusion STIR 3-in-1 b600; (B) diffusion STIR b600, 4.4 x 4.4 x 3 mm. Small nodule was located on the soft tissues of the right thigh (red circle).

Discussion

The patient has several small lesions suspected to be secondary bone lesions from her primary cancer, melanoma. Having the ability to detect these lesions on the patient's arms, iliac joint and thigh will enable the oncologist to re-stage the cancer and adapt therapy.

Whole-body DWI is an excellent option for evaluation of metastatic bone lesions compared to PET/CT and scintigraphy. It provides good image quality and provides the information clinicians need for patient management.

Even if PET/CT were recommended, this type of system is not available in all regions and is often more expensive than MR. Scintigraphy exposes the patient to additional radiation and MR has been found to provide similar sensitivity and specificity for patients with a small number of bone lesions, 58% sensitivity/33% specificity for whole-body DWI MR versus 67% sensitivity/58% specificity for scintigraphy; and patients with multiple bone lesions, 97% sensitivity/91% specificity for whole-body DWI MR versus 48% sensitivity/42% specificity for scintigraphy.[2]

With MR, we can avoid patient exposure to additional radiation dose and achieve a high sensitivity and specificity for detection of metastatic lesions. Additionally, the strong magnet homogeneity on the SIGNA™ Explorer helps to decrease distortion when imaging large FOVs and "3-in-1" diffusion STIR provides the thin-slice data needed for a confident diagnosis in shorter scan times.

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Transforming the MR imaging experience for one of Sweden's largest pediatric hospitals

As part of a modernization project, The Queen Silvia Children's Hospital upgraded to the SIGNA™ Architect with AIR Technology™‡. An initial evaluation by the Department of Pediatric Radiology found the new AIR Technology™ Anterior Array (AA) delivers good SNR and homogeneity for high-resolution imaging. The coil also enables flexibility and ease of positioning patients, and when used with AIR Touch™ makes coil selection easier and helps with workflow.

As one of the largest pediatric hospitals in Sweden, The Queen Silvia Children's Hospital at Sahlgrenska University Hospital in Gothenburg provides care to children from newborns up to age 18. The Department of Pediatric Radiology performs around 45,000 exams each year. Named for the country's current Queen, the hospital has undergone a modernization project to improve workflow and enhance clinical services as well as create a safe and secure healing environment for its young patients.

The pediatric radiology department recently upgraded its Discovery™ MR750w 3.0T wide-bore system to SIGNA™ Architect. With new gradients and Total Digital Imaging (TDI), the cutting-edge platform is designed to help facilities like The Queen Silvia Children's Hospital adapt to existing and future advancements in MR imaging technologies, such as AIR Technology™ and the SIGNA™Works productivity platform.

"We want to be on the front line of new technology and prepare for the future," says Håkan Boström, MD, pediatric radiologist at The Queen Silvia Children's Hospital.

In addition to the recently upgraded SIGNA™ Architect, the hospital also has an Optima™ MR450w 1.5T. Combined, these two MR systems enable the hospital to perform more than 2,000 MR exams each year.

According to Pär-Arne Svensson, MR research radiographer, a key motivation behind the SIGNA™ Architect upgrade was the ability to acquire the new AIR Technology™ Suite, including the 48-channel Head Coil, along with new MR sequences available in SIGNA™Works, specifically MUSE, PROPELLER MB (multi-blade), MPRAGE and distortion correction with diffusion-weighted imaging (DWI) like PROGRES.

The radiology department has been evaluating MUSE as a replacement sequence for single-shot diffusion imaging in neonates. With MUSE, Dr. Boström can obtain higher resolution and the distortion correction is better with less distortion artifacts. In addition to Dr. Boström finding that MUSE delivers high resolution and excellent image quality, PROPELLER MB is also helpful in avoiding metal artifacts. PROPELLER MB is particularly beneficial when imaging the cervical spine and temporal bone with diffusion sequences. Svensson and Dr. Boström

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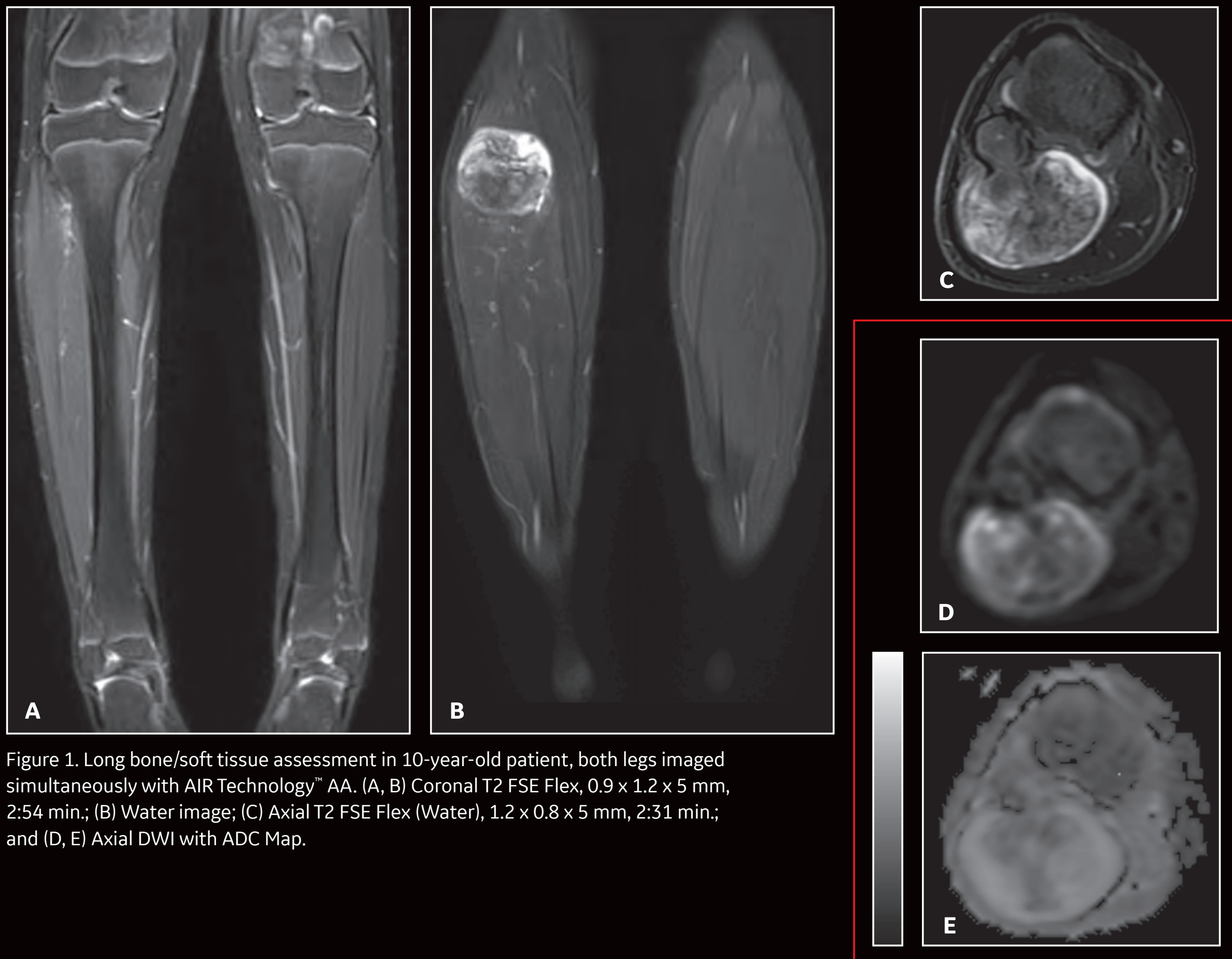

Figure 1. Long bone/soft tissue assessment in 10-year-old patient, both legs imaged simultaneously with AIR Technology™ AA. (A, B) Coronal T2 FSE Flex, 0.9 x 1.2 x 5 mm, 2:54 min.; (B) Water image; (C) Axial T2 FSE Flex (Water), 1.2 x 0.8 x 5 mm, 2:31 min.; and (D, E) Axial DWI with ADC Map.

are still evaluating MPRAGE, however, they are obtaining better contrast between white and gray matter in the brain compared to other conventional 3D FSPGR sequences. This sequence would be particularly helpful when imaging epilepsy patients before and after surgery.

In addition to the new sequences, the department received the AIR Technology™ AA and 48-channel Head Coil in early 2019. The AIR Technology™ AA has the highest channel count and coverage in the industry.

"Our initial experience is very good," says Dr. Boström. "We've used the AA for several exams, such as the abdomen, pelvic, lower extremities, shoulder and fetal imaging. The main advantages with the AIR Technology™ AA are the flexibility and ease of positioning on the patient."

It is lightweight—60 percent lighter than conventional, hard-shell coils—and children in pain may not tolerate a heavy coil on their body, Dr. Boström explains. This includes children who had open heart surgery at The Queen Silvia Children's Hospital, one of only two pediatric cardiac surgery centers in Sweden.

"Fetal imaging is another area where we see an advantage with the AIR Technology™ AA," adds Svensson. "It can be difficult to put a conventional, hard-shell coil around a pregnant woman's abdomen and get a good, homogeneous signal."

For women in the late stage of pregnancy, lying on their back can be uncomfortable. Svensson wants to try imaging them on their side with the AIR Technology™ AA wrapped around them and see what the impact is on patient comfort and image quality.

In musculoskeletal imaging of the shoulder and arm, lower extremities or imaging both legs, Svensson can wrap the coil around larger field-of-views (FOVs) and obtain a homogenous signal for good image quality. For example, patients with multifocal chronic osteomyelitis or muscular dystrophy/myositis will often require imaging of both legs simultaneously.

"With the AIR Technology™ AA, we can cover large areas but we also get good SNR, so we can provide detailed images of specific joints with high resolution," he says.

Positioning these precious patients is also easier now with AIR Technology™. There are many factors that can impact the overall time a child is in

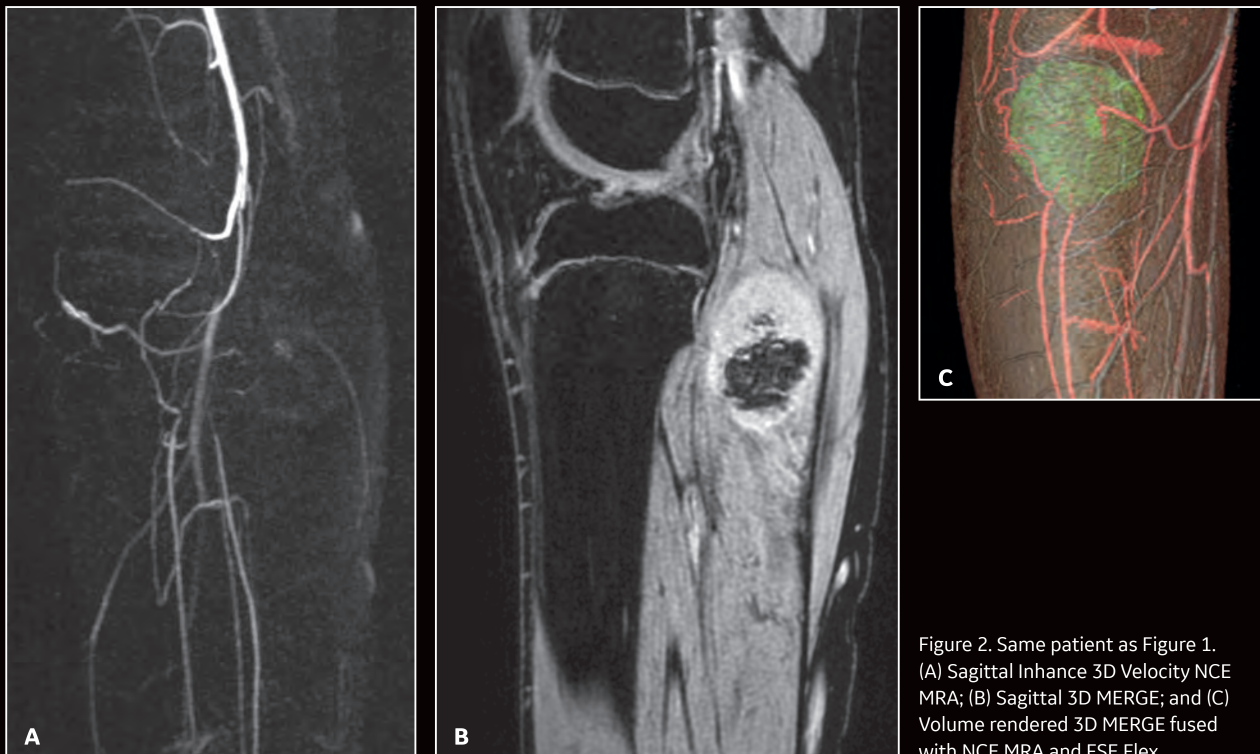

Figure 2. Same patient as Figure 1. (A) Sagittal Inhance 3D Velocity NCE MRA; (B) Sagittal 3D MERGE; and (C) Volume rendered 3D MERGE fused with NCE MRA and FSE Flex.

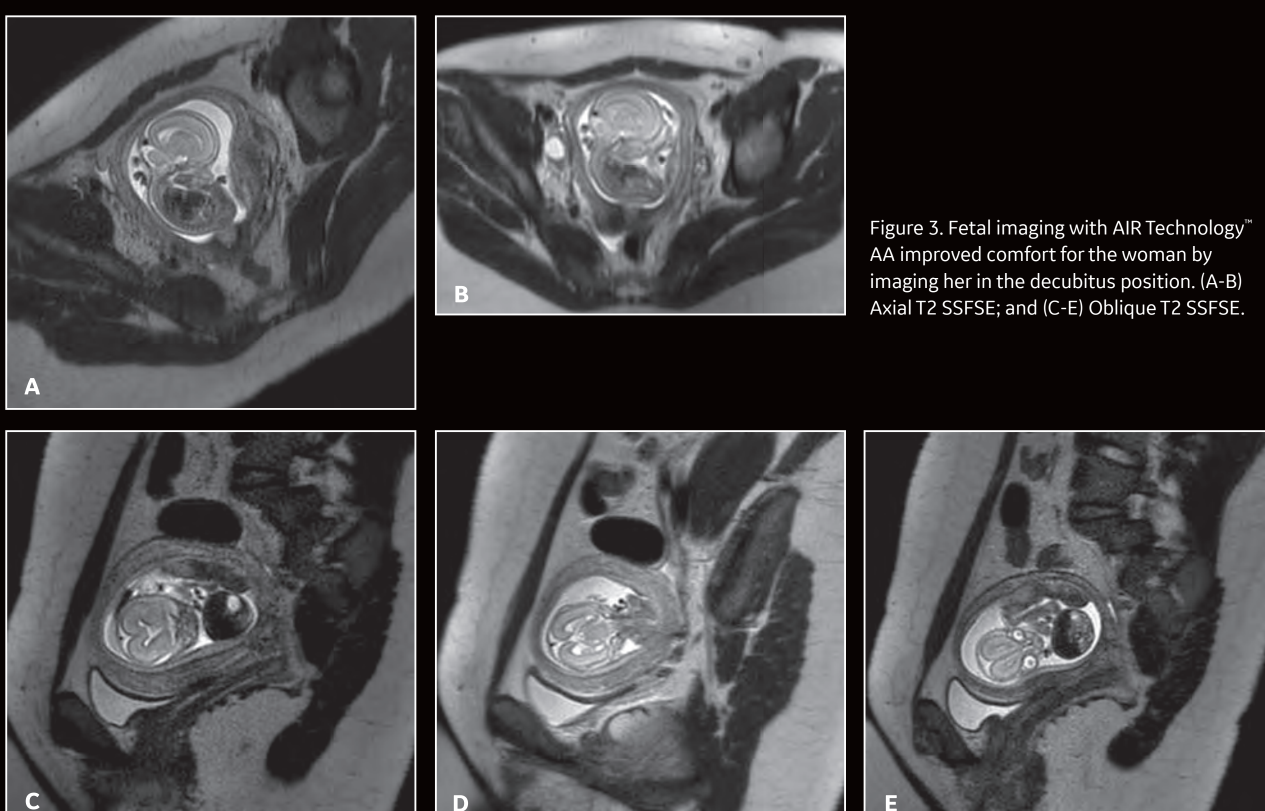

Figure 3. Fetal imaging with AIR Technology™ AA improved comfort for the woman by imaging her in the decubitus position. (A-B) Axial T2 SSFSE; and (C-E) Oblique T2 SSFSE.

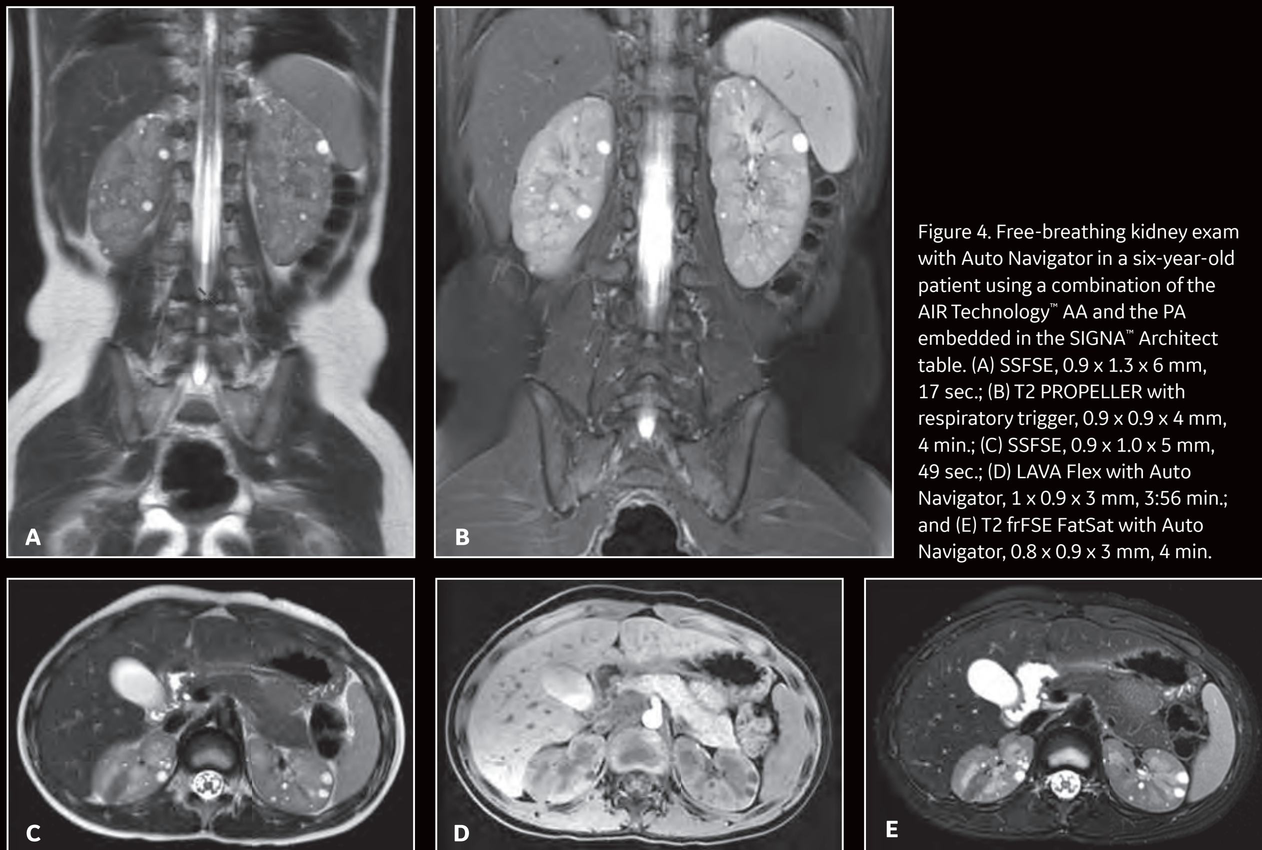

Figure 4. Free-breathing kidney exam with Auto Navigator in a six-year-old patient using a combination of the AIR Technology™ AA and the PA embedded in the SIGNA™ Architect table. (A) SSFSE, 0.9 x 1.3 x 6 mm, 17 sec.; (B) T2 PROPELLER with respiratory trigger, 0.9 x 0.9 x 4 mm, 4 min.; (C) SSFSE, 0.9 x 1.0 x 5 mm, 49 sec.; (D) LAVA Flex with Auto Navigator, 1 x 0.9 x 3 mm, 3:56 min.; and (E) T2 frFSE FatSat with Auto Navigator, 0.8 x 0.9 x 3 mm, 4 min.

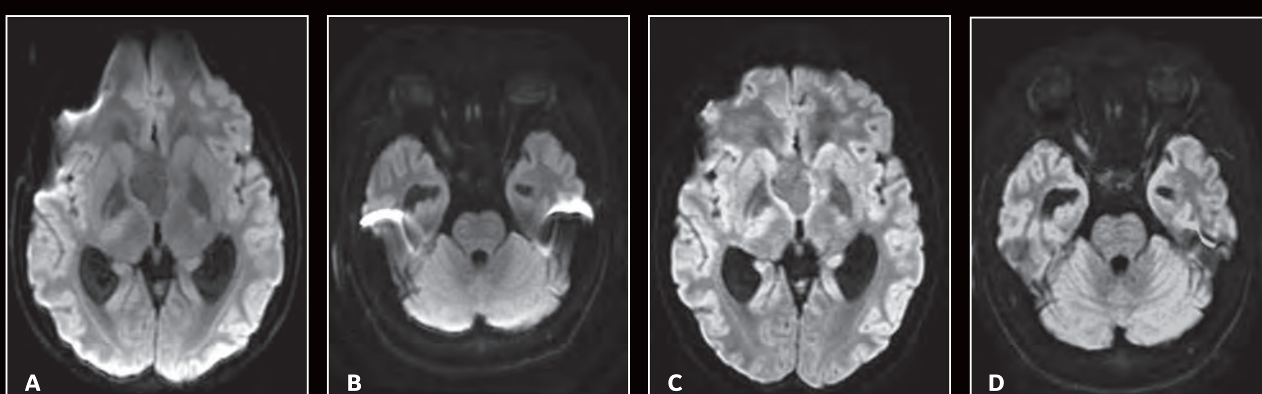

Figure 5. Neuro imaging with the 48-channel Head Coil in a three-year-old patient. Note the same resolution with less blurring in the MUSE DWI sequence. (A-B) Traditional single-shot DWI, 1.8 x 1.4 x 3.6 mm, 2 shots, acceleration factor of 2, 1:58 min.; and (C, D) MUSE DWI, 1.8 x 1.4 x 3.6 mm, 2 shots, acceleration factor of 2, 2:16 min.

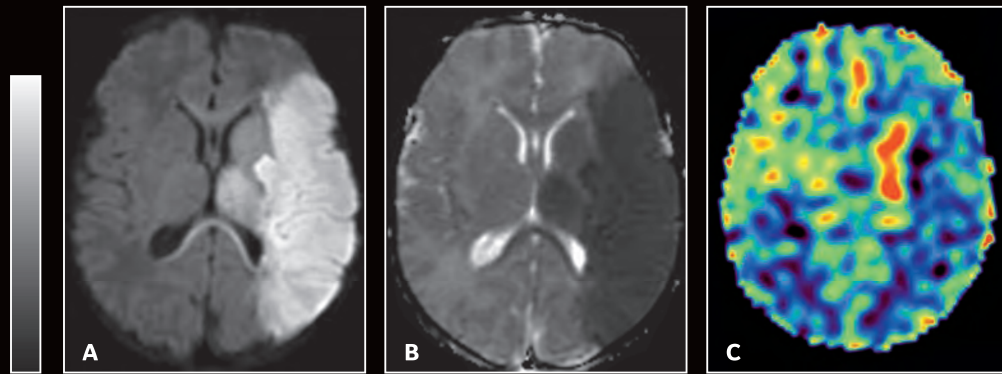

Figure 6. Neuro imaging with the 48-channel Head Coil in a three-day-old patient. (A-B) MUSE DWI with ADC Map, 1.2 x 1 x 3 mm, 3:09 min.; and (C) Axial ASL CBF Map.

the MR scanner and any time saved in positioning means the sooner the patient can get back to his or her parents.

Another patient-centric feature of AIR Touch™ is that it assists with patient positioning. It automatically selects the best elements to use and uniquely optimizes uniformity, SNR, artifacts and parallel imaging.

"AIR Touch™ makes coil selection much easier and I don't have to check what elements are activated because the system does it. It helps with workflow, but the most important factor is that it helps me focus more on the child."

Pär-Arne Svensson

AIR Touch™ even helps when using more than one coil. Embedded in the SIGNA Architect™ table is the Posterior Array (PA). With small children, Dr. Boström and Svensson are using GE's Flex Coil in combination with the PA. They have seen excellent results using the combination of both coils in cardiac and abdominal exams.

After using the impressive AIR Technology™ AA for just two months Svensson and Dr. Boström no longer use the conventional AA. They look forward to receiving the new AIR Technology™ Multi-Purpose (MP) Coil, a smaller version of the AIR Technology™ AA.

There have been a few patients who had MR exams with both the conventional coil and the AIR Technology™ AA. Svensson says when asked, these patients preferred the new coil, especially because it was not so heavy and confining on their bodies.

"The most important benefit of AIR Technology™ is the patient comfort," says Dr. Boström. "It is lightweight and can lay on the patient like a blanket. We believe this also impacts patient compliance."

Overall, Dr. Boström and Svensson are impressed with SIGNA™ Architect, SIGNA™Works and especially AIR Technology™.

"This is a stable MR system with very good image quality," says Svensson. "We are satisfied with the upgrade and our initial experience with AIR Technology™."

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Alexander Hirsch, MD
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AIR Technology: a brilliant improvement in high-quality imaging and patient comfort

As one of the first sites in the world to install SIGNA™ Premier and AIR Technology™‡, Erasmus Medical Center is a leader in adopting cutting-edge technologies. These new solutions are providing a better patient experience while delivering high-quality imaging and advanced applications, further enhancing the excellent care provided by clinicians at Erasmus.

Erasmus Medical Center in Rotterdam, Netherlands, is a leading university medical center in Europe and has long been recognized for its adoption of cutting-edge technologies and advanced medical solutions. For the last few years, Erasmus has collaborated with GE Healthcare to evaluate the introduction of new technologies into the clinical environment. One of these is AIR Technology™.

AIR Technology™ Coils are designed to fit all patients, allow flexibility in any direction and closely wrap around the patient's anatomy for greater visibility of hard-to-scan areas with excellent image quality. By conforming to the patient habitus and bringing the coil elements closer to the patient, AIR Technology™ improves signal quality and signal-to-noise ratio (SNR) and reduces imaging artifacts when compared to previous generations of conventional coil technology.

Recently, several clinicians from Erasmus shared their initial impression of AIR Technology™ on the SIGNA™ Premier 3.0T MR system, including the AIR Technology™ Anterior Array (AA), the 48-channel Head Coil and AIR Touch™.

Cardiac imaging

Alexander Hirsch, MD, cardiologist, specializes in non-invasive cardiac imaging. In cardiac patients, Dr. Hirsch scans cardiomyopathy and ischemic heart disease patients on SIGNA™ Premier. Typically, the 2D FIESTA, first-pass perfusion and MDE images are the most common sequences for these patients.‡‡ Image quality is important, particularly in the late enhancement (MDE) sequence where Dr. Hirsch evaluates myocardial viability. With the 2D FIESTA sequence, he is looking at cardiac function. However, 2D FIESTA sequences have historically been problematic at 3.0T.

"The new SIGNA™ Premier system is especially good for late enhancement images and also for perfusion," Dr. Hirsch says. "I was able to see the anatomy and the function, as well as differentiate the contrast between the blood and the myocardium. Previously in a 3.0T system, that was a problem, however, with the SIGNA™ Premier this has improved a lot."

A key factor in the improved image quality is AIR Technology™. Dr. Hirsch says he gets a more homogeneous signal and better contrast between the blood and the myocardium.

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Juan Hernandez Tamames, PhD

Erasmus Medical Center
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Watch Dr. Hirsch's 2019 SCMR presentation, "Getting consistent and quantifiable results in cardiac imaging:" https://youtu.be/dQ3-sU-kPv0

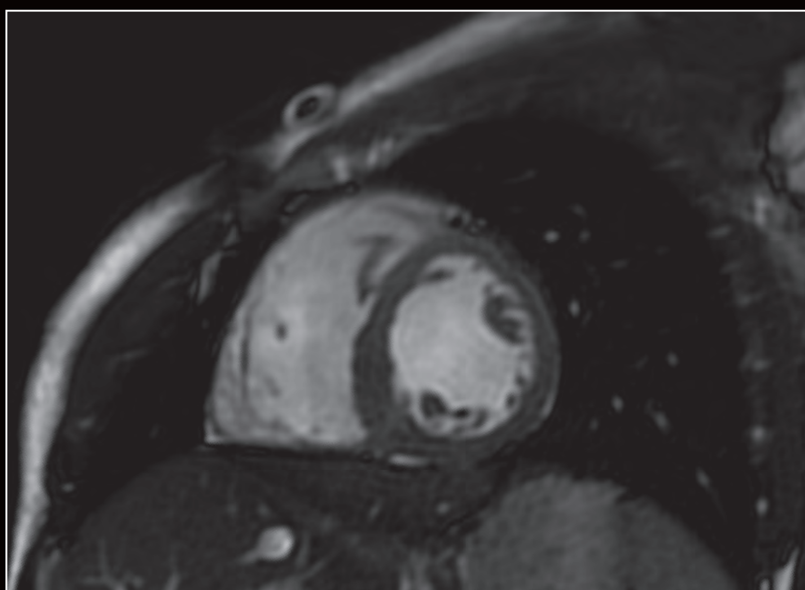

Figure 1. Short axis 2D FIESTA. The combination of SIGNA™ Premier and AIR Technology™ delivers high SNR and high image quality for excellent cardiac MR imaging results at 3.0T.

"Because of the specialized nature of our facility, with referrals from all over the Netherlands, it is important to have the latest technology," he says. "With the new GE SIGNA™ Premier and AIR Technology™, we can provide high-quality care for our patients."

"The new AIR Technology™ AA has a major advantage in that it helps provide high image quality," Dr. Hirsch adds. Plus, with SIGNA™ Premier he has been able to achieve high SNR, which is very important for the sequences he is using. Dr. Hirsch also expects to see improvements in 4D Flow (ViosWorks), as well as the new 3D MDE sequence.

"When we started working with SIGNA™ Premier, I was pleasantly surprised to see the image quality, especially for the 2D FIESTA sequence," he says.

Brendan Bakker, MR radiographer, has developed cardiac MR (CMR) protocols at Erasmus with Dr. Hirsch. While 1.5T was typically preferred for CMR, he worked with Dr. Hirsch to evaluate CMR exams on the SIGNA™ Premier 3.0T MR system with AIR Technology™.

"The AIR Technology™ AA is brilliant and it's an improvement for the patient. It is very easy to handle, very lightweight and the quality is very good for cardiac imaging, especially on the SIGNA™ Premier system," Bakker says.

"AIR Technology™ is very flexible, you can put it around the chest or stomach but also use it around the knee or shoulders," Bakker says. "With other coils that are more rigid, this is not possible."

In pediatric imaging, the AIR Technology™ Coils fit almost like a blanket on the child, he adds.

MSK imaging

Edwin Oei, MD, PhD, is an Associate Professor of Musculoskeletal Imaging and Section Chief of Musculoskeletal Radiology at Erasmus Medical Center. He dedicates half his time to research and working with MR physicists and PhD students to improve technologies and apply MR imaging in population health studies.

"SIGNA™ Premier offers advantages in musculoskeletal imaging because of its higher gradient performance, especially when it is used with the AIR Technology™ Coil," Professor Oei says.

According to Professor Oei, musculoskeletal (MSK) MR imaging tends to suffer from artifacts and movement more than in other body parts. Often, there are difficulties with positioning patients due to their injury or ailment, as well as using the right coil. While coil selection is not as problematic in the knee or ankle, it can be more difficult when imaging the shoulder, wrists or ribs.

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Erasmus Medical Center
Rotterdam, Netherlands

Jean Paul Laarhoven
Erasmus Medical Center
Rotterdam, Netherlands

"With AIR Technology™, we are more flexible in choosing the coil, which allows for imaging specific body parts with greater accuracy. For patients with chronic diseases such as arthritis, it may not be easy for them to lie still in the scanner for a long time with a rigid coil. AIR Technology™ is lighter and more comfortable for the patient so, indirectly, I think it will also reduce movement artifacts. "

Professor Edwin Oei

AIR Technology™ also assists with patient positioning. When using traditional rigid coils, the body part being imaged had to be positioned precisely in the coil. With AIR Technology™, this is less of an issue.

"We mainly now use the blanket-type AA Coil and have achieved great imaging results in the chest wall and in joints," adds Professor Oei. "I think AIR Technology™ is beneficial for diverse patient groups, including pediatric and elderly patients."

Professor Oei believes there is a movement in MR imaging toward whole-body imaging, particularly for oncology. He anticipates that AIR Technology™ will provide excellent results over existing coil technology due to its wide coverage.

"Since the introduction of SIGNA™ Premier and AIR Technology™ at Erasmus, I've seen image quality improve over previous scans and I believe that AIR Technology™ can greatly improve patient throughput," Professor Oei says.

The AIR Technology™ Suite also includes a 48-channel Head Coil. Jean Paul Laarhoven, MR radiographer, has scanned patients with both the 48-channel Head Coil and the AIR Technology™ AA on SIGNA™ Premier. With the ability to adjust the coil for larger-sized heads and necks, he can accommodate more patients. He has found that patients with anxiety or claustrophobia can better tolerate the 48-channel Head Coil because the front part of the coil is slightly smaller and doesn't cover the patient's entire face.

"You can immediately see the high-quality images that the AIR Technology™ Coil captures," Laarhoven explains. "Of course, we also have the AIR Technology™ Posterior Array (PA) in the table so we only have to position the AIR Technology™ AA on top of the patient."

Improving the patient experience

Sita Ramman has been an MR radiographer for nearly 28 years at Erasmus. Often, she has had to comfort and reassure patients who are nervous about their MR exams. She will explain that they have to remain very still and may have to hold their breath while the system acquires the images.

Since the introduction of AIR Technology™, she has seen a noticeable difference.

"The patients like the AIR Technology™ Coils because they are very lightweight and flexible, and mold to the patient's anatomy," Ramman says. "For us, it is very easy to position. You just put it on the patient and that's it. That's all you have to do."

She has also used AIR Touch™, an intelligent coil localization and selection tool that enables automatic coil element selection and uniquely optimizes uniformity and SNR. AIR Touch™ informs the system when the coil is connected, allows the technologist to landmark the patient with a single touch and even optimizes the element configuration. Coil coverage, uniformity and parallel imaging acceleration are generated dynamically to optimize image quality. A simplified user interface allows the technologist to focus on the patient and also maximizes examination efficiency.

"We just put the AIR Technology™ Coil on the patient, localize using the AIR Touch™ button on the table and move the patient inside the SIGNA™

Sita Ramman
Erasmus Medical Center
Rotterdam, Netherlands

Figure 2. AIR Technology™ Suite is flexible and assists with patient positioning in areas where coil selection may be more difficult, such as the wrist. (A) Coronal 3D MERGE; (B) Coronal PD FatSat; and (C) Coronal T2 Flex.

Premier," Ramman explains. "With AIR Technology™ and AIR Touch™, we don't need to do any calibration as it is done automatically. This makes a difference in our daily routine because it takes less time to position a patient."

A remarkable advance

Juan Hernandez Tamames, PhD, Associate Professor (MR) and Head of the MR Physics group in the radiology department at Erasmus, facilitates the introduction of new technology in MR imaging for both clinical and research purposes.

"SIGNA™ Premier incorporates several new approaches and breakthroughs in technology," Professor Tamames says. "For example, the AIR Technology™ Coils are one of the most remarkable innovations I've seen because they increase SNR."

He also discovered that the HyperBand capability on SIGNA™ Premier enables the possibility to simultaneously scan several slices, accelerating acquisition with the potential to shorten scan times when using DWI. With the parallel transmission, he can tailor the RF for specific tissues in a more appropriate way.

"Compressed sensing is another remarkable advance on SIGNA™ Premier," Professor Tamames adds. "When used with AIR Technology™, which improves signal due to the closer proximity to the patient anatomy and tissue, we can increase the acceleration with compressed sensing and parallel imaging to reduce scan times."

For example, since the lungs are filled with air, it is often difficult to obtain good SNR. Because the AIR Technology™ AA lays on the patient's chest, it is as close to the body as possible. This enables a high SNR.

Another advantage is in pediatric imaging. Professor Tamames says a baby can be wrapped in the coil, which makes them more comfortable and enables the coil to get closer to the anatomy.

"In general, AIR Technology™ is more convenient and it can fit almost any sized anatomy," adds Professor Tamames.

Professor Tamames is interested in testing the AIR Technology™ AA with a conventional head coil and also with the 48-channel Head Coil.

"With 48-channels we can accelerate more because we have a really good, high-quality signal," Professor Tamames

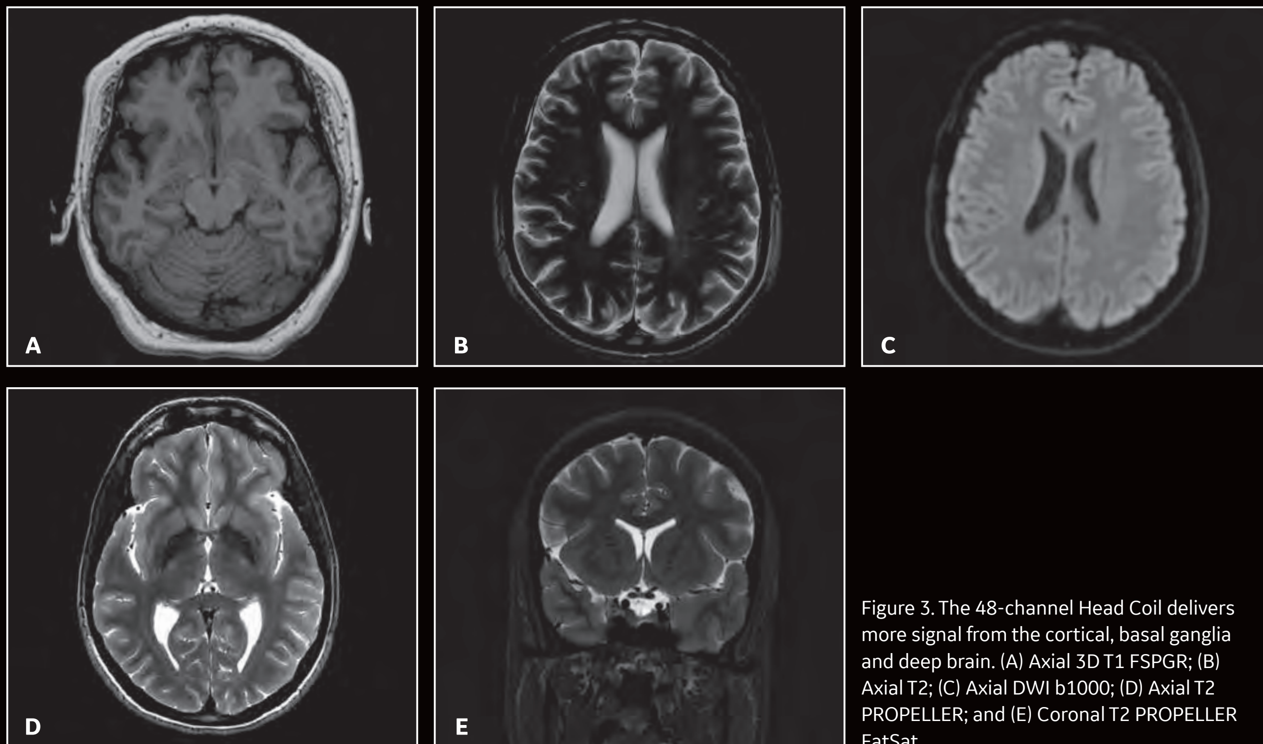


Figure 3. The 48-channel Head Coil delivers more signal from the cortical, basal ganglia and deep brain. (A) Axial 3D T1 FSPGR; (B) Axial T2; (C) Axial DWI b1000; (D) Axial T2 PROPELLER; and (E) Coronal T2 PROPELLER FatSat.

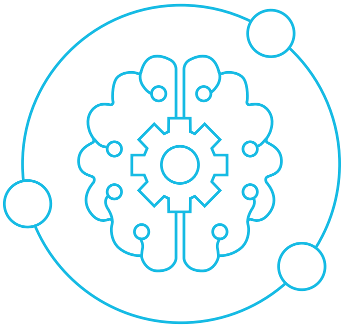
explains. “By accelerating, we reduce the echo time, which means less distortion in an EPI sequence. And that is important for exploring the basal ganglia and frontal or temporal areas. Not only is the signal better, but the anatomy and morphology of the tissue is more realistic.”

And, because the headset for the 48-channel Head Coil is compatible with EEG systems, clinicians at Erasmus can simultaneously record EEG and capture MR images. Professor Tamames also sees the potential for continued innovation in technology and sequences to shorten MR scan times, in some cases to as quick as five or 10 minutes.

“I think SIGNA™ Premier and AIR Technology™ are paving the way to achieve this goal,” Professor Tamames adds.

‡‡Drug products should be used in accordance with their approved labeling. Gadolinium-based contrast agents have not been approved for cardiac use in all regions.

Watch the team at Erasmus discuss their experience with AIR Technology™.
https://youtu.be/MeGebBSjUNQ



Tom Schrack, ARMRIT, MRSO
Fairfax Radiological Consultants
Fairfax, Virginia

New deep learning tool streamlines MR slice prescription

A new deep learning software from GE Healthcare is helping streamline MR scan prescription that may help reduce inconsistencies in imaging across patients and technologists. **AI**Rx™‡ is an AI-based, automated workflow tool for MR brain scanning that automatically "prescribes" slices to help reduce redundant, manual steps. It uses deep learning algorithms built right into the MR technologist's workflow to automatically detect and prescribe slices for neurological exams, delivering consistent and quantifiable results. **AI**Rx™ also helps produce images that have less variability between technologists and between scans, helping to lower the chances a patient will be recalled due to incorrect slice placement. An increase in consistency is particularly important when doing longitudinal assessments on patients with diseases that progress over time.

"Every time I select a landmark for the prescription, the slice placement is dead on," says Tom Schrack, ARMRIT, MRSO, Manager of MR Education and Technical Development at Fairfax Radiological Consultants in Fairfax, Virginia.

Schrack and two other senior technologists at Fairfax Radiological Consultants have used a prototype of **AI**Rx™ – which stands for Artificial Intelligence prescription (AI Rx) – since early November 2018, conducting about 15 cases on their facility's 3.0T SIGNA™ Architect MR scanner.

Deep learning for faster imaging

AIRx™ is built on Edison, a new platform that helps accelerate the development and adoption of AI technology and empower providers to deliver faster, more precise care. Edison is a holistic, integrated digital platform for healthcare, combining globally diverse data sets from across modalities, vendors, healthcare networks and life sciences settings.

It enables GE Healthcare to integrate and assimilate data from disparate sources, apply advanced analytics and AI to transform the data, and generate insights to support clinical, financial and operational decision-making. Edison includes deployment-agnostic intelligent applications and smart devices, designed to help achieve greater efficiency, increase access to care, and improve patient outcomes.

By leveraging this platform, **AI**Rx™ features a pre-trained neural network model that leverages deep learning algorithms and anatomy recognition based on a database of over 36,000 images sourced from clinical studies and reference sites.

AIRx™ helps increase productivity by simplifying workflow steps, thus significantly reducing user prescription time. A study showed average prescription time savings can be up to 62%.‡‡

It precisely places slices on the smallest and most challenging neurological anatomy, such as optic nerves. "Everything that it says it can find, it finds it with amazing accuracy," says Schrack. "For example, if I tell **AI**Rx™ that I want an oblique sagittal of the left optic nerve, it puts a slice right down the center of that left optic nerve. **AI**Rx™ does that immediately and perfectly, every time. It can save me some eye strain, save time from tweaking parameters, and get me going a little bit faster."

Schrack says **AI**Rx™ is one step in the right direction of fulfilling the promise of AI, with the potential to use it on complicated anatomy such as the heart and joints, while continuing to simplify the technologist's job.

"You'll never hear a technologist say, 'I wish this was harder to use,' or 'I wish the machine would stop automating tasks for me'," says Schrack. "They want the machine to make decisions for them so that it's easier, and I think the only way that's going to happen is with deep learning and artificial intelligence. For the technologist, anything that reduces the number of decisions in an MR exam will make their job better." S

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‡‡According to an internal study conducted by GE Healthcare.

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An upgrade that meets the expectation for higher resolution, SNR and productivity

After upgrading its SIGNA™ Architect to the latest SIGNA™Works productivity platform and acquiring the AIR Technology™‡ Anterior Array (AA), Osaka University Hospital is delivering exceptional MR imaging that also promotes patient-centered care—two tenets of the hospital's core philosophy. The combination of these three advanced technologies is delivering excellent image uniformity across a wide range of patients and clinical exams.

For nearly 150 years, Osaka University Hospital (originally Osaka Medical School, circa 1869) has served the residents of Osaka and fostered the education of medical professionals throughout the region. The hospital's dedication to providing high-quality medical care is centered on the belief that adopting new and advanced technologies further promotes patient-centered, safe and reliable holistic care that contributes to the society.

"At Osaka University Hospital, we always seek the latest innovative technology to provide the best clinical performance and patient care," says Masatoshi Hori, MD, PhD, Associate Professor, Department of Radiology at Osaka University Hospital. With this philosophy, the department recently upgraded its existing Discovery™ MR750w 3.0T to SIGNA™ Architect and also acquired the AIR Technology™ AA.

"Our key expectation for MR is higher resolution, higher signal-to-noise ratio and higher temporal resolution," Professor Hori says. "This upgrade completely meets our expectations."

He found the AIR Technology™ AA to be lighter than expected and anticipates it will provide a better patient experience during an MR exam. Technologists have also shared with him that patient and coil set-up is much easier and that SNR gains are being realized because, in most cases, the coil fits the many shapes and sizes of patients much better than conventional arrays.

"The AIR Technology™ AA is one of the biggest innovations I have seen in the last decade," adds Professor Hori. He believes it will become a future standard technology and is excited to be an early adopter.

An important benefit of AIR Technology™ is the ability to utilize higher parallel imaging acceleration factors with the coil element configuration and lower g-factor of the new coils. Specifically, in a 640 x 640 matrix T2-weighted PROPELLER Multi-shot Blade (MB) FatSat pancreas exam, high-resolution images were obtained with an ARC factor of 4 in 4:24 minutes (Figure 1).

PROPELLER MB is one key enhancement that Professor Hori is routinely using. It combines multiple blades together to achieve shorter TEs and improved motion correction. PROPELLER MB is also compatible with Auto Navigator, a free-breathing approach to combat respiratory motion in the body, cardiac and chest imaging with automatic tracker placement.

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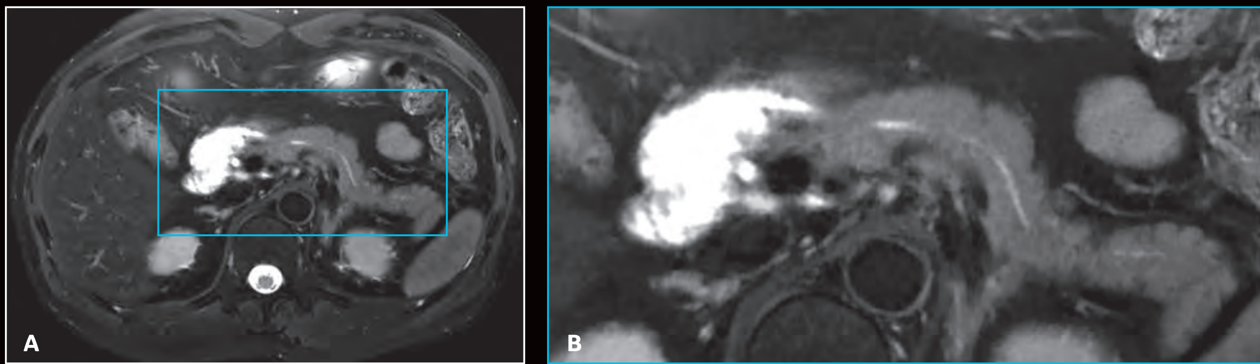

Figure 1. AIR Technology™ enables the use of higher parallel imaging factors with improved SNR for high-resolution imaging and reduced scan times. (A) Axial T2w FatSat acquisition with PROPELLER MB, 0.6 x 0.6 x 4 mm, ARC factor of 4, 4:24 min.; (B) ROI in (A) magnified.

Figure 2. A female weighing 287 lbs. (130 kg) referred for MR imaging of the pelvis. (A) Sagittal T2w frFSE, 0.8 x 0.9 x 4 mm, 6:08 min.; (B) Sagittal T2w PROPELLER MB, 0.9 x 0.9 x 4 mm, 3:02 min.

"We are now using PROPELLER MB for all abdominal cases, such as pelvis, liver and pancreas," he says. "There is also the additional big advantage of motion correction without any critical disadvantage."

For example, he obtained good contrast of the endometrium and junctional zone in a patient without motion artifact. In the upper abdomen, he acquired good images that were also not compromised due to motion (Figure 2).

It's not just the coil that is leading to excellent imaging results at Osaka University. Professor Hori found the combination of the SIGNA™ Architect, advanced sequences and AIR Technology™ together deliver robust imaging with excellent image uniformity.

"Sometimes we needed different WW/WL adjustments so we could clearly see the anatomy between the center and the edge of the FOV to make a diagnosis. Now, we no longer need to make this change in most patients," he says (Figure 3).

Professor Hori evaluated the AIR Technology™ AA and a conventional AA in a patient exam. He discovered that with the latest uniform correction application, reFINE, he could acquire higher image quality and better uniformity in many clinical cases and contrasts.

"Also, I found the AIR Technology™ AA provides better signal penetration, so image quality and SNR are better than a conventional coil, especially in large patients," he adds.

Using HyperCube with the AIR Technology™ AA in prostate imaging, Professor Hori can perform thin-slice imaging. He acquires 1-2 mm slice 3D images with HyperCube and obtains good quality compared to conventional 2D 5 mm Axial imaging. The advantage is that the thin slices provide him with a better understanding of capsular invasion, which can impact patient management and treatment options (Figures 4 and 5).

Multi-plexed Sensitivity Encoding (MUSE) DWI is another impressive application, especially in the prostate. It provides both high SNR and high spatial resolution.

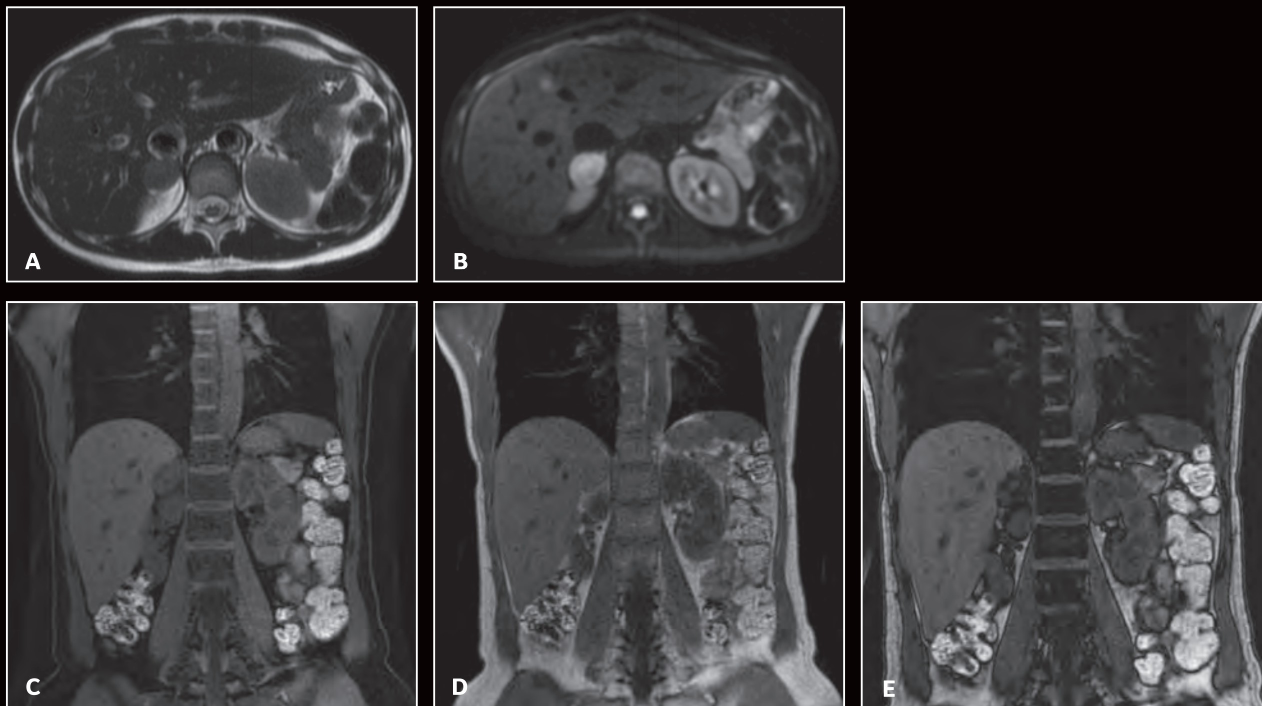

Figure 3. Patient with an adrenal mass. (A) Axial T2w SSFSE, 1.1 x 1.8 x 5 mm, 18 sec.; (B) Axial DW-EPI, 2.8 x 2.8 x 5 mm, 3:49 min. (RTr); (C-E) Coronal LAVA Flex, 1.4 x 1.6 x 3 mm, 16 sec.; (C) water, (D) in-phase and (E) out-of-phase.

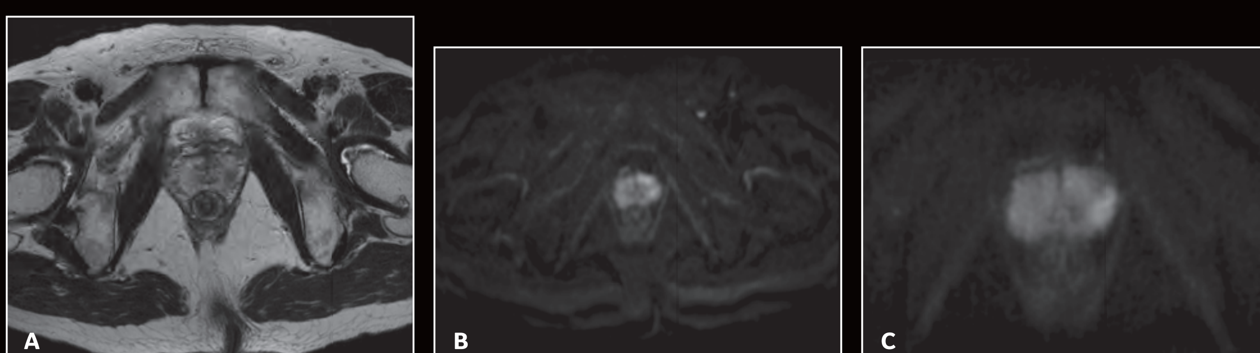

Figure 4. Prostate cancer patient (A) Axial T2w PROPELLER MB, 0.6 x 0.7 x 4 mm, 3:25 min; (B) EPI DWI b1000, 2.3 x 2.3 x 4 mm, 2:08 min.; and (C) FOCUS DWI, b1000, 1.5 x 1.5 x 4 mm, 4:10 min.

"Currently, we acquire both conventional EPI DWI for the whole pelvis and FOCUS DWI for targeted small FOV with high resolution," Professor Hori explains. "However, MUSE can provide high-quality imaging in both larger and smaller FOV for the prostate," (Figure 6).

In MRCP imaging, HyperSense is shortening scan times by 30 percent at Osaka University. He has also increased matrix size, from 512 x 320 to 512 x 416. With this protocol, he can more clearly see the small intrahepatic bile duct with less motion due to the shortened scan time (Figure 7).

Looking forward, Professor Hori wants to evaluate the use of AIR Technology™ in exams that require wide scan coverage, from the upper to the lower abdomen. This coil has the highest channel count and coverage in the industry today.

"With the AIR Technology™ AA, 65 cm wide coverage might be very beneficial for these types of studies," he adds.

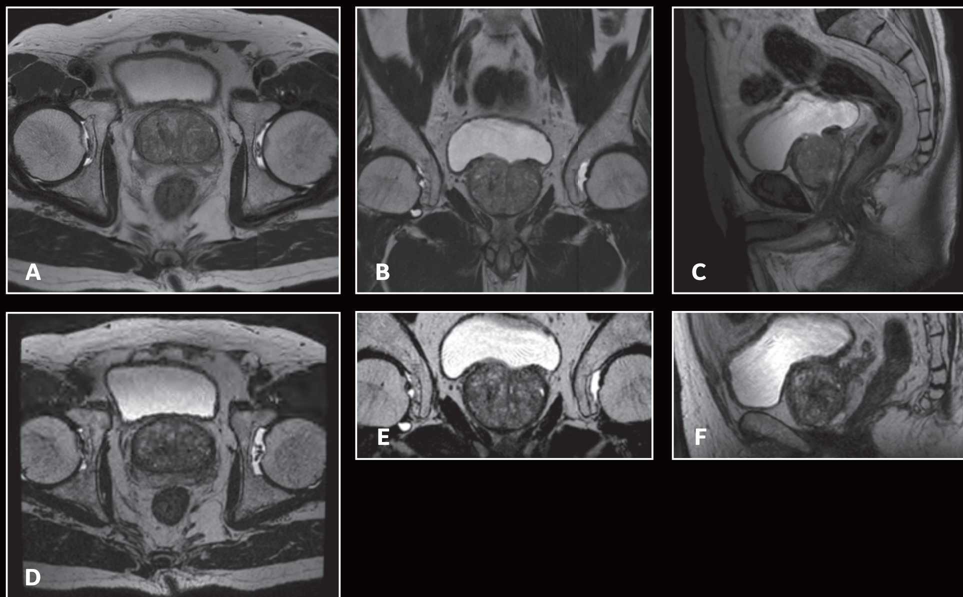

Figure 5. Prostate exam using HyperCube. (A-C) Conventional 2D T2w in 3 planes. (D-F) T2w with HyperCube enables (E-F) thin-slice imaging. (A) Axial T2w, 0.6 x 0.8 x 4 mm, 3:42 min.; (B) Coronal T2w, 0.6 x 0.8 x 4 mm, 3:25 min.; (C) Sagittal T2w, 0.6 x 0.8 x 4 mm, 2:36 min.; and (D-F) T2w with HyperCube acquired in the Axial plane and reformatted to (E) Coronal and (F) Sagittal, 0.9 x 0.9 x 2 mm, 3:54 min.

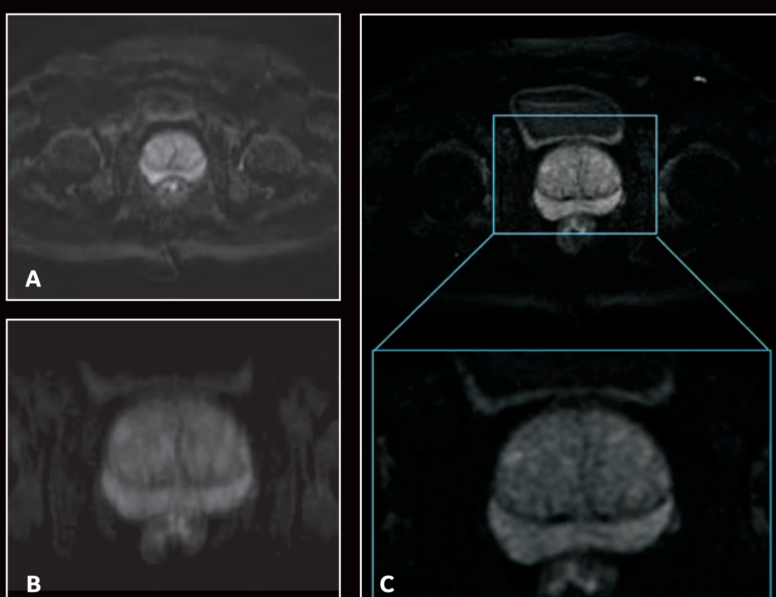

Figure 6. Patient referred for prostate exam.
(A) DWI b1000, 2.3 x 2.3 x 4 mm, 2:08 min.;
(B) FOCUS b1000, 1.5 x 1.8 x 4 mm, 4:10 min.; and
(C) MUSE 3 shot b1000, 1.6 x 1.6 x 4 mm, 4:15 min.

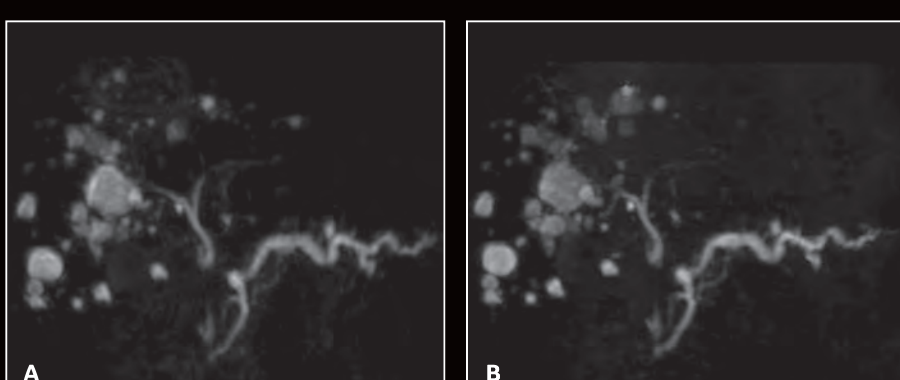

Figure 7. Comparison of MRCP exam with and without HyperSense. Scan time was reduced 30% with HyperSense. (A) Conventional MRCP RTr, 0.7 x 1.1 x 1.6 mm, 3:51 sec. and (B) MRCP RTr with HyperSense, 0.7 x 0.9 x 1.6 mm, 2:45 min.

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Ultra-flexible AIR Technology Suite making a difference in the technologist's workflow

The AIR Technology™‡ Suite simplifies patient positioning and setup with AIR Touch™ automatic coil and element selection, a 60 percent lighter design than prior generations of coil technology and a flexible design that fits patients of various sizes and shapes.

Kawasaki Saiwai Hospital in Kanagawa, Japan, installed the SIGNA™ Architect 3.0T MR system in late 2017. In February 2019, the hospital upgraded to the latest version of the SIGNA™Works productivity platform and acquired the AIR Technology™ Suite. As one of the main healthcare providers for the region, especially for acutely ill patients, the hospital embraces the concept of patient-centered healthcare. The AIR Technology™ Anterior Array (AA) conforms to the human body, is flexible to fit all shapes and sizes and has a 60 percent lighter design compared to previous generations of conventional coil technology—making it the ideal coil to deliver both patient comfort and high image quality at Kawasaki Saiwai Hospital.

Takafumi Naka, RT(R)(MR), Chief Technologist, evaluated the new system and coils and the impact on the technologist's workflow and patient experience. He was most impressed that the AIR Technology™ AA is ultra-flexible and can be wrapped around the patient to facilitate positioning and fits a variety of patient body sizes.

In musculoskeletal (MSK) extremity imaging, coil selection for MR exams of the humerus and antebrachial bone would require two coils to image from the shoulder to the elbow. The AIR Technology™ AA, however, covers a larger region of interest (ROI) with a comfortable wrap-around fit and a higher SNR. Naka expects the same results in lower extremity imaging, particularly for patients with cellulitis and muscle contusions where large ROIs need to be acquired.

A conventional heavy, hard-shell coil on a patient's chest could impact the respiratory detection device, so Naka would place a spacer between the coil and the patient.

"However, with the AIR Technology™ AA, we no longer have to do that," Naka says. "We now have better patient positioning workflow and also get an improvement in SNR because the coil is closer to the patient's chest."

In addition, he does not have to worry about setting the coil center because AIR Touch™ automatically detects it, providing additional workflow improvements and removing the chance for human error.

Naka is also thrilled that he can use higher parallel imaging acceleration factors with the AIR Technology™ AA. In one case, he applied a factor of 4x for a body Coronal DWI and had less distortion and blurring than with a conventional coil (Figure 1).

"It was a single-shot EPI DWI, however, the anatomy detail and information was really amazing," he adds.

Naka has also used higher parallel imaging acceleration factors in body PROPELLER exams. He leveraged this capability for better image quality, such as refocusing the flip angle for higher T2 contrast. He sees the same impact in neuro imaging with the 48-channel Head Coil.

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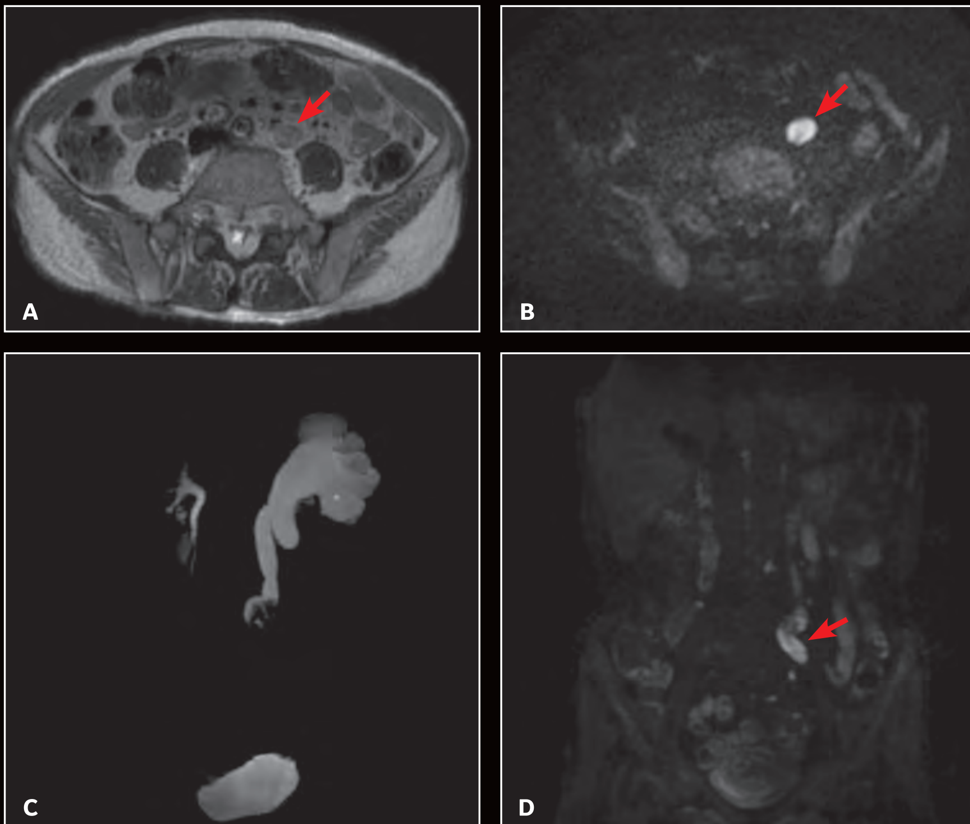

Figure 1. High-resolution MR Urography with reduced scan time is possible using HyperSense and HyperCube. A urethral tumor was visualized on the Coronal DWI using long axis. Even with an ASSET factor of 4.0, there was low distortion in the diffusion-weighted images. All images acquired with the AIR Technology™ AA. (A) Axial T2w SSFSE, 1.3 x 1.4 x 4 mm, 1:28 min.; (B) Axial DWI b1000, 2.7 x 2.7 x 4 mm, 3:57 min.; (C) MR urography, 0.7 x 1.2 x 1.4 mm, 2:40 min. (RTr); and (D) Coronal DWI b800, 3.1 x 1.6 x 4.5 mm, ASSET factor 4, 4:27 min. (RTr).

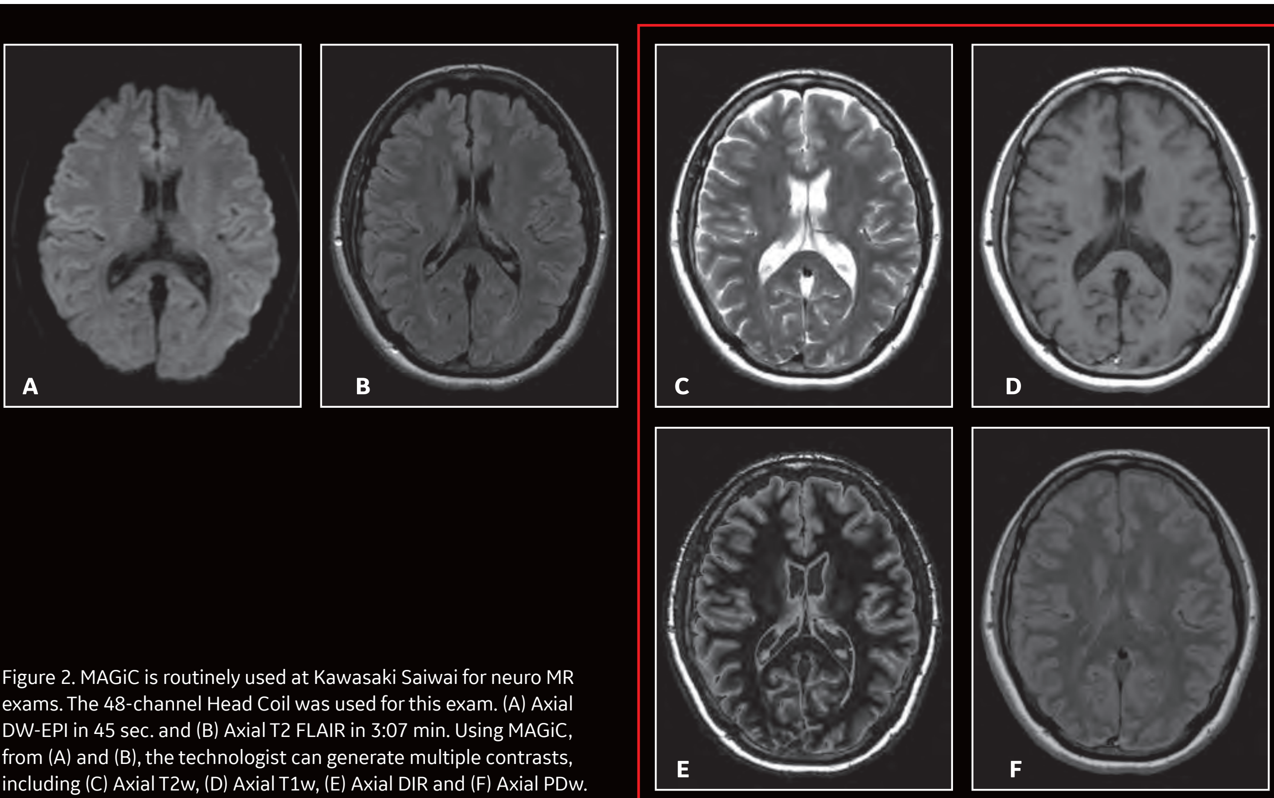

Figure 2. MAGiC is routinely used at Kawasaki Saiwai for neuro MR exams. The 48-channel Head Coil was used for this exam. (A) Axial DW-EPI in 45 sec. and (B) Axial T2 FLAIR in 3:07 min. Using MAGiC, from (A) and (B), the technologist can generate multiple contrasts, including (C) Axial T2w, (D) Axial T1w, (E) Axial DIR and (F) Axial PDw.

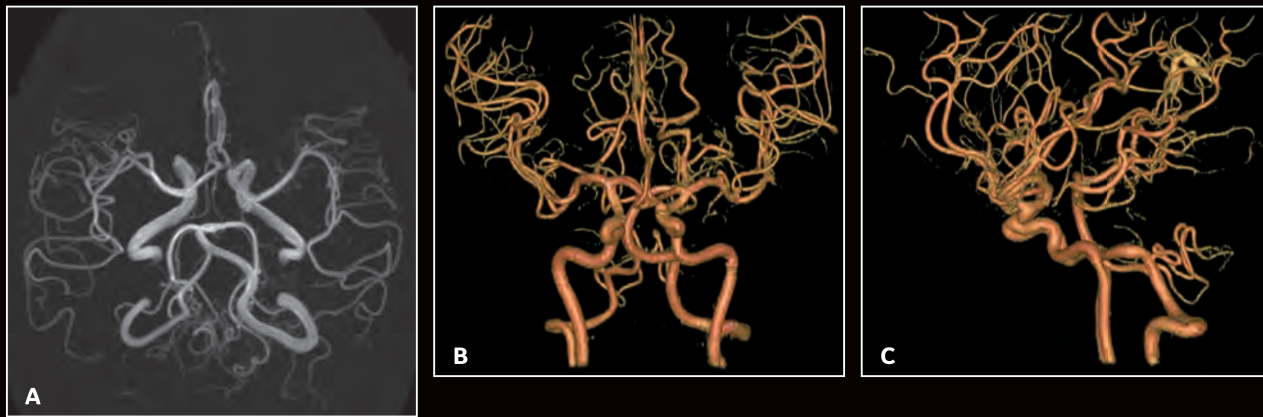

Figure 3. (A-C) TOF MRA with HyperSense factor of 2.5 and ARC factor of 2, 0.4 x 0.5 x 0.8 mm, 6:06 min.

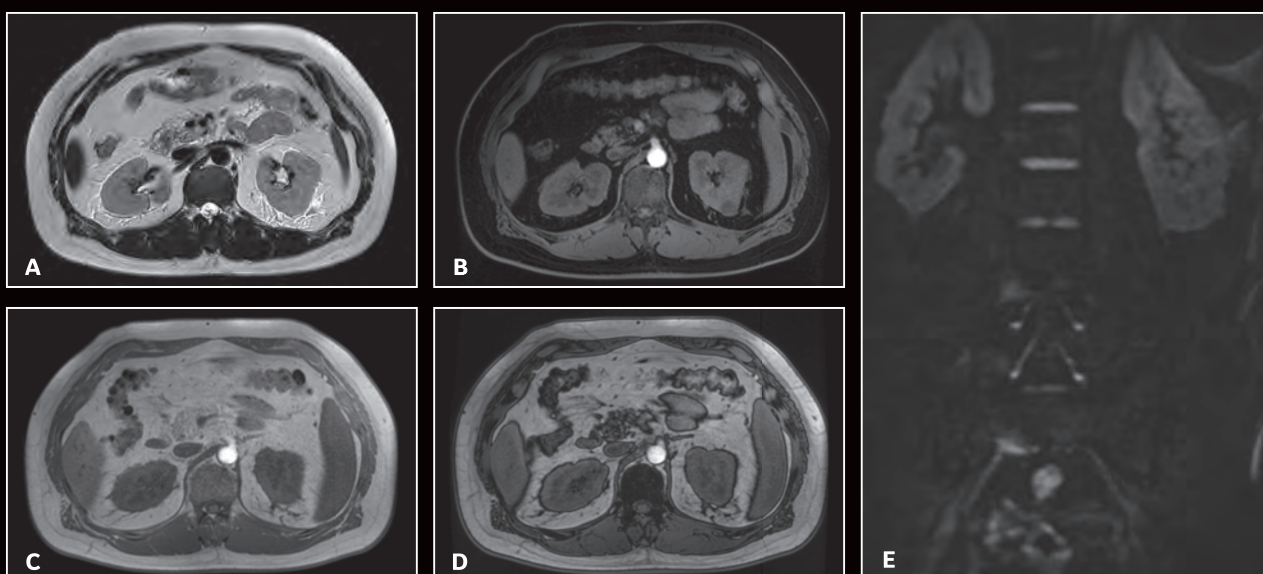

Figure 4. Patient weighed over 200 lbs. (120 kg). Abdominal kidney exam using the AIR Technology™ AA required a wide FOV, however, highly uniform images were acquired. (A) Axial T2w PROPELLER MB, 0.8 x 0.8 x 5 mm, ASSET 4.0, 5:39 min.; (B-D) Axial LAVA Flex; (B) water; (C) in-phase; (D) out-of-phase: 1.6 x 1.6 x 4 mm, 14 sec.; and (E) Coronal DWI b900, 3.1 x 1.6 x 5 mm, ASSET 4.0, 4:20 min.

"We already use MAGiC in clinical routine neuro examinations to acquire excellent T1 contrast, which by principle is difficult to obtain at 3.0T," Naka says. "However, with the 48-channel Head Coil, we can reduce the scan time from six to three minutes because of the higher SNR," (Figure 2).

Plus, the 48-channel Head Coil allows Naka to use a higher HyperSense factor because of the high SNR and spatial resolution. As a result, he can now acquire a high-resolution MR angiography exam in six minutes—something that previously took approximately 20 minutes (Figure 3).

He has noticed that patients are more relaxed with the AIR Technology™ AA than with conventional coils. Even large-sized patients weighing over 200 lbs. can fit comfortably inside the MR, with space between the coil and the bore (Figure 4).

Kawasaki Saiwai Hospital also installed the latest version of the SIGNA™Works productivity platform with SIGNA™ Architect. Naka loves the improvements in DWI, especially MUlti-plexed Sensitivity Encoding technique (MUSE) and PROGRES.

"The most impressive application is MUSE, a multi-shot DWI that allows us to achieve quite high spatial resolution compared to conventional DWI," he explains. "I find that MUSE DWI provides us completely different image quality versus the conventional sequence."

Figure 5. MUSE acquires high resolution DWI even at high b-values (b1000) and by using 4 shots with ARC acceleration of 1, distortion can be reduced. Fusing Sagittal T2w PROPELLER MB with the ADC map does not lead to distortion even in the presence of rectal gas. (A) Sagittal MUSE b1000, 1.5 x 0.9 x 6 mm, 4 shots with ARC acceleration of 1, 5 NEX, 4:39 min.; (B) Sagittal T2w PROPELLER MB, 0.8 x 0.8 x 6 mm, 4:12 min.; and (C) Fused ADC map with Sagittal T2w PROPELLER MB.

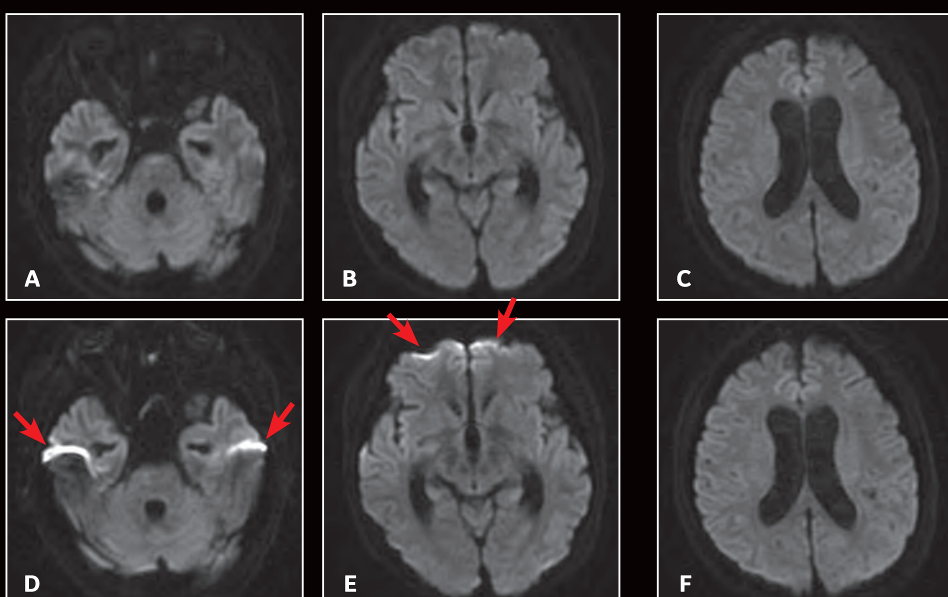

Figure 6. (A-C) DWI with PROGRES; and (D-F) conventional DWI. PROGRES provides less distortion than conventional DWI sequences, including fewer susceptibility artifacts (arrows) around the eye and inner ear.

In particular, the improvement in female pelvis imaging is notable. MUSE DWI clearly depicts details of cervix and endometrial lesions when Naka sets the acquisition plane (slices) along the uterine axis (Figure 5).

"We could see almost no distortion even in the Sagittal plane and there was less artifact from rectal gas," explains Naka. "Surprisingly, when we fuse MUSE DWI with T2-weighted images, we could not find misregistration caused by distortion. So, we think high-resolution MUSE DWI will have an advantage in detecting small lesions in the pancreas."

After investigating several sequences, Naka and his colleagues found PROGRES provided the best DWI image with the least distortion. Susceptibility artifacts around the eye and inner ear were decreased with no major impact on scan time when using PROGRES. As a result, PROGRES is being frequently used for neuro DWI at Kawasaki Saiwai Hospital (Figure 6).

From streamlined patient positioning to greater patient comfort, Naka sees the difference that AIR Technology™ has on the patient experience. For his department, the ability to use higher acceleration factors and save time in patient set-up will positively impact the technologist's workflow, further improving staff satisfaction. And, with the new sequences available in SIGNA™Works, he and his team can deliver the excellent image quality clinicians need for a more confident diagnosis. S

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MR Excellence Program is a beacon for optimizing MR imaging workflow and the patient experience

The MR Excellence Program and Imaging Insights dashboards unlock clinical value and operational efficiency through data intelligence and human expertise for targeted, individualized patient care. By measuring the current status of MR imaging throughout a department or center, facilities can improve MR imaging services to enhance the delivery of care and the patient experience.

Kirchberg Hospital, part of the Robert Schuman Hospital Foundation, is a multi-disciplinary healthcare provider situated in the Kirchberg quarter of Luxembourg City, Luxembourg. Comprised of four facilities—the Clinique Bohler, specializing in OB/GYN; the ZithaKlinic, a free-standing multi-specialty clinic; the Clinique Sainte-Marie, specializing in geriatric medicine; and Kirchberg Hospital. The facilities were organized under one foundation with the goal to further modernize and enhance the quality of care delivered to the residents of Luxembourg.

On average, 200,000 imaging exams are performed yearly across all four sites. Combined, the facilities have three MR systems, three CT scanners, seven radiology rooms, two mammography systems and four ultrasound machines. Since 2011, Kirchberg Hospital has collaborated with GE Healthcare in the evaluation of new solutions, including DoseWatch, GE's dose management solution, in 2011 and the MR Excellence Program in 2018.

The MR Excellence Program combines machine-based data intelligence (Imaging Insights analytics) with human expertise (customer success experts) to unlock clinical value and operational efficiency within a radiology department. It uses LEAN and Change Acceleration Process tools to help department managers and staff better understand the data and make the appropriate decisions to enact clinical and operational improvements.

Imaging Insights is a set of dynamic and comprehensive dashboards that provide key acquisition and analytic measures that radiology department staff rely on to deliver excellence in imaging services. A multi-modality and vendor agnostic solution, Imaging Insights combines machine data with workflow data from radiology information systems to measure key performance indicators (KPIs) in radiology.

As Radiology Manager for all four facilities under the Robert Schuman Hospital Foundation, Paolo Sana is committed to digitizing healthcare and elevating quality through advances in imaging technology. He was involved in the DoseWatch evaluation while in a prior position at the hospital and has been a key contributor to the evaluation of MR Excellence. The hospital has a SIGNA™ Artist 1.5T that performs on average 6,900 exams each year.

"The MR Excellence Program allows us to evaluate the impact of the operation and clinical improvements we took, step-by-step, to allow for a stable and sustainable change in our department," Sana says.

The MR Excellence Program was implemented at Kirchberg Hospital to help harmonize protocols across the same clinical indication, optimize scheduling times and monitor MR utilization and performance.

"When you discover the Imaging Insights dashboards, it is similar to when you discover the dashboard of your new car for the first time. Very quickly, you become familiar with it and can configure the dashboards to make them more useful and comprehensive to your facility and your specific clinical or operational needs."

Paolo Sana

Sana credits the development of a data team at Kirchberg Hospital during the DoseWatch evaluation and the inclusion of the staff that uses the SIGNA™ Artist each day for the success of the program. It is that teamwork and the feedback that helped drive decisions.

"We need the input of people from the field, who are most able to compare the data to their experiences so that the analysis and decisions fit with the clinical reality," he adds.

Sandrine Debelle, Radiographer and MR Excellent Program Leader at Kirchberg Hospital, agrees with Sana's assessment that a key first step is to customize the dashboards to the department and facility.

"You want consistency between the analytics and what is happening in the clinical routine," Debelle says. "Depending on your goals, the KPI indicators can be very different."

Since Kirchberg Hospital was involved in the test and pilot phase in the development of MR Excellence, there was a lot of communication and feedback with GE, including a team of digital experts. The collaboration between GE digital experts and the data team at Kirchberg Hospital was a main factor for the project's success.

Working with GE's digital experts as a part of the MR Excellence Program also helped Debelle tailor the indicators to the hospital's specific goals. She refers to this collaboration and guidance as the hospital's GPS, helping to sort out the tremendous volume of data that can be pulled from the Imaging Insights dashboards.

"Do not underestimate the importance of the data team," adds Sana. "They are really the pillars of the project and should be the first thing put in place before starting this type of project."

As a result of the successful pilot project, Kirchberg Hospital has purchased the MR Excellence solution and Debelle is excited at the prospect of implementing it.

The pilot project

Several key areas were targeted for the pilot evaluation project using Imaging Insights dashboards at Kirchberg Hospital: scheduling, protocol standardization, clinical excellence and patient experience.

"Without hesitation, MR Excellence improved scheduling for MR exams. Thanks to the dashboard analytics, we were able to quickly compare the schedule duration to the actual exam time. We then adjusted our exam scheduled slots so they fit with reality. As a result, we had an 11 percent increase in the volume of knee exams in just a few weeks, for example."

Paolo Sana

Figure 1. Patient throughput by weekday and hour of the day.

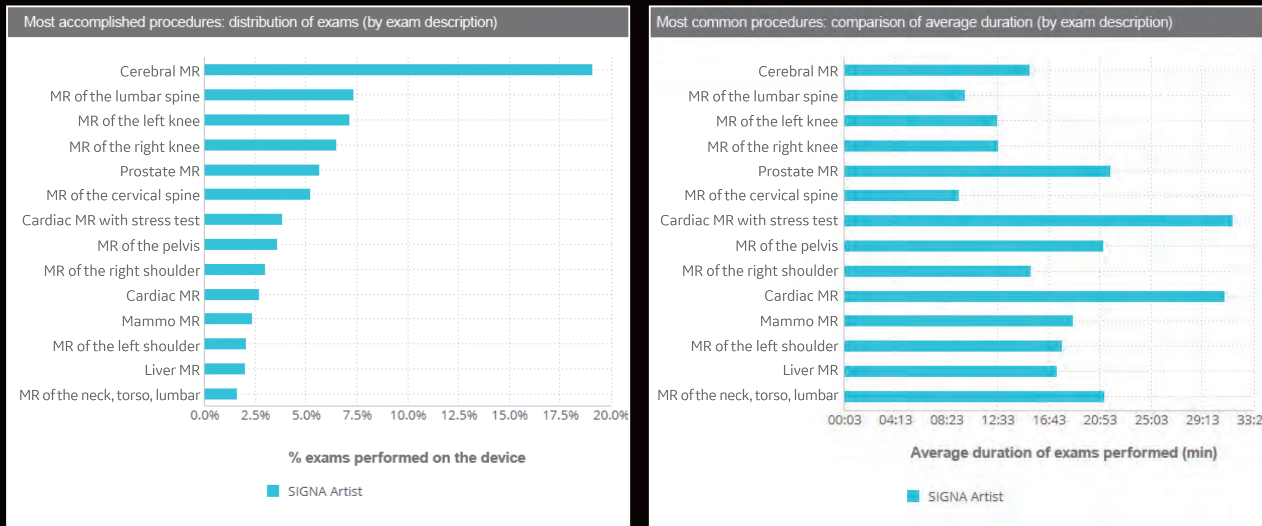
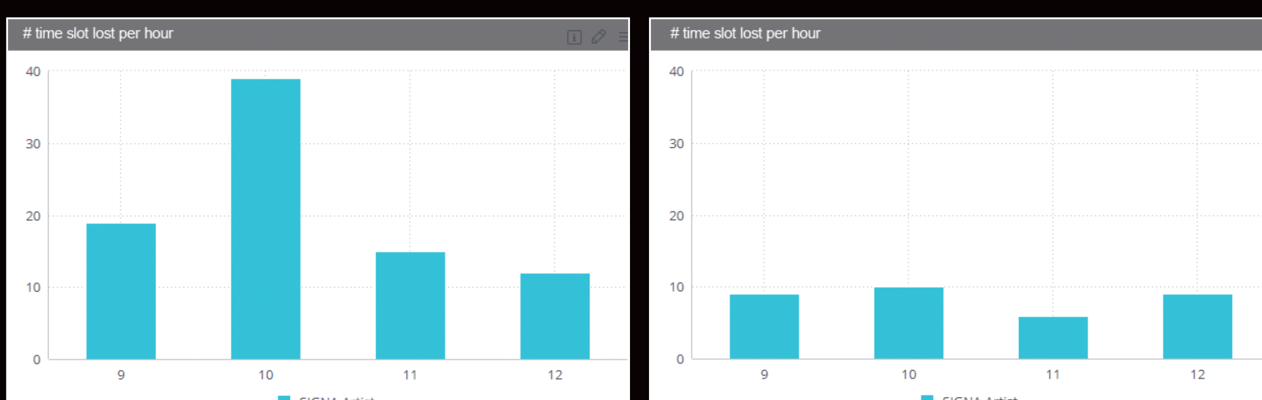


Figure 2. A comparison of the most common MR exams (distribution) with the average exam duration.

Study description	System	# exams	Status	% difference	Scheduled slot (min.)	Total appointment time (min.)	Setup time before exam	Exam duration P75 (min.)	Setup time after exam (min.)
Cerebral MR	SIGNA Artist	618	●	8.9%	20	22	2	18	2
Cardiac MR with stress test	SIGNA Artist	333	●	16.1%	40	46	5	36	5
Cardiac MR	SIGNA Artist	223	●	11.2%	40	44	4	36	4
Prostate MR	SIGNA Artist	126	●	2.6%	30	29	2	25	2
Liver MR	SIGNA Artist	117	●	30.0%	20	26	2	22	2
MR of the left knee	SIGNA Artist	101	●	24.2%	15	19	2	15	2
MR of the right knee	SIGNA Artist	96	●	23.3%	15	18	2	14	2
MR of the lumbar spine	SIGNA Artist	93	●	10.4%	15	17	2	13	2
MR of the right shoulder	SIGNA Artist	86	●	13.3%	20	23	3	18	2

Figure 3. A comparison of the scheduled versus actual exam slots led to a reduction in appointment times for several common MR exams.



Before (Q4'17) After (Q3'18)

Figure 4. With the Imaging Insight dashboards, inactive time of the MR scanner was quantified, leading to a change in scheduling rules.

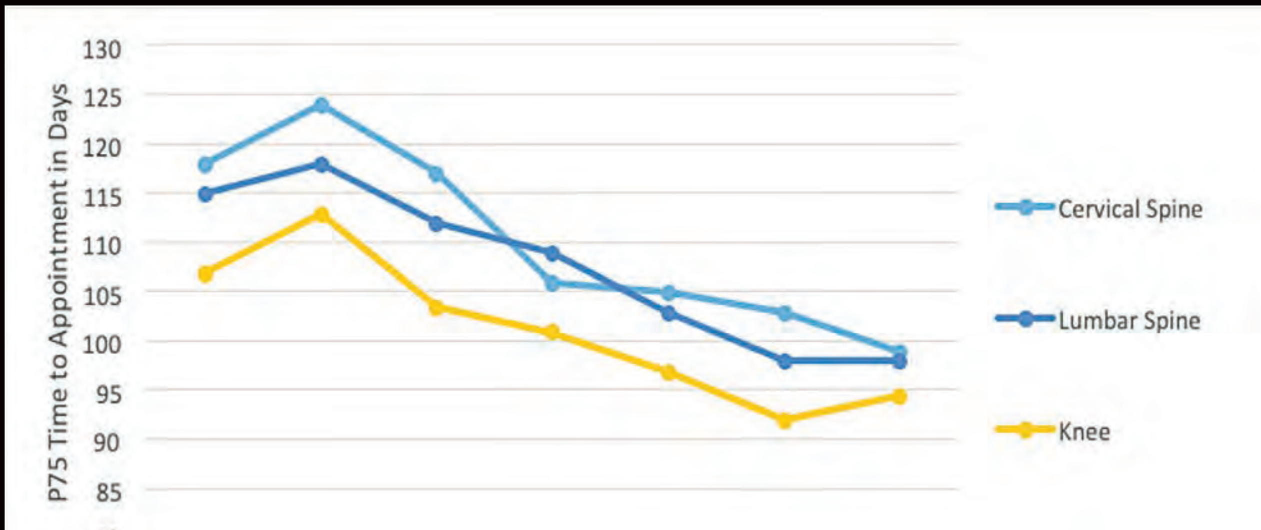


Figure 5. Waiting times decreased by approximately 15 days.

In addition to evaluating the schedule for knee exams, the team also analyzed lumbar spine and cervical spine exams and found that the scheduling for all three exams could be reduced to 15-minute slots. This increased the volume of exams but also shortened patient wait times to get an appointment.

"This impact shows how using the dashboard analysis to make a decision can improve the patient experience. It has also changed the way our staff works with the introduction of MR Excellence. There has been less downtime because we can detect inactivity slots, understand why they are happening and take action to reduce them."

Paolo Sana

According to Debelle, any change made based on the Imaging Insights dashboard data goes through a step-by-step process. The data team first follows the indicators and analyzes the data. Then, modifications are proposed and communicated to all stakeholders. With the Imaging Insights dashboards, she could analyze exam duration with exam distribution to identify the most common and most lengthy MR exams (Figures 1 and 2).

For example, the first step is to assess throughput for each day and each hour of the day. Then, by evaluating the exam mix and average duration, Debelle can investigate how to improve quality of care and workflow. She can compare scheduled exam times with the actual appointment time (Figure 3) and MR system downtime (Figure 4) to quantify the time that the SIGNA™ Artist is idle and not scanning patients.

"From this data, we were able to determine that at 10 am and 11 am, we had 20 minutes of inactivity, or no patient scanning, in the MR room," Debelle explains. "By changing our scheduling rules, we were able to reduce the inactivity by almost 30 percent for a more consistent patient workflow."

The result has been a 15 percent increase in patient throughput, or an average of 16 more exams each week. Further, patient wait time to get an appointment for a knee, lumbar spine or cervical spine exam—the hospital's top three MR procedures—decreased by 15 days (Figure 5).

Protocol standardization was another key area where Kirchberg Hospital utilized the power of MR Excellence to measure and quantify variability.

"We have always placed a priority on our radiologists' opinions and their different ways of working and reading studies," says Sana. This process, common for many hospitals, led to changes in protocols and an increase in the number of protocols for a particular exam.

Consistency of studies is a factor in the overall quality of MR imaging, from the image acquisition to the interpretation. Plus, having more protocols means it takes more time and work to optimize each variation for image quality and acquisition time.

Protocols used in Q4'17 for the head exam

Study protocol name	# exams SIGNA Artist
1 CRANE HK	228
1 CRANE	83
1. HYPOPHYSE	16
1.CAI HK	10
1 CRANE REDUCTION ACOUST	4
ORL	4
1 CRANE ACCUSTIC REDUCTI	2
1 CRANE AVC HK	1
1 CRANE AVC	1
1 CRANE PEDIA	1
1 CRANE FLEX CLAUSTRO	1

Protocols used in Q3'18 for the head exam

Study protocol name	# exams SIGNA Artist
1 CRANE HK	400
1. HYPOPHYSE HK	29
1 CRANE AVC	26
1.CAI HK	9
1 CRANE ACCOUSTIC REDUCT	6
ORL	1

Figure 6. A 47 percent decrease in the number of protocols.

Using the Imaging Insights dashboard, Debelle was able to analyze protocol variations by exam type. She could also see which protocols were most often utilized. Based on this analysis, the department decreased the number of protocols on the SIGNA™ Artist by 47 percent (Figure 6).

"Every protocol is now optimized for image quality and acquisition time and dedicated to the particular indication," Debelle says. As an example, the department had 11 protocols for a head exam prior to the MR Excellence Program; after implementing the MR Excellence Program, the hospital has six protocols for head exams.

An improved imaging experience

The MR Excellence Program allows Debelle to be more aware of the many factors that can influence patient workflow. Through the Imaging Insights dashboard, the MR Excellence Program enables her and her team to find new ways to improve workflow, scheduling, clinical excellence and the patient experience.

"Participating in the pilot evaluation of the MR Excellence Program has allowed me to discover a new, important facet of my job that is very closely tied to the MR exam," says Debelle. "This data allows us to find areas of improvement in the planning and workflow that really enable a team approach to embrace and implement change."

A key facet of the program was to create buy-in from the staff at all levels. Sana and Debelle shared the goals with the MR team, specifically how the data could help improve patient management and workflow and create a more efficient and productive working environment.

"We wanted the MR team to see the data and dashboard as a tool that facilitates our daily work and allows the caregiver to spend more time with the patient," says Sana. "The entire digitization of the hospital in general is to enhance the quality of care we can deliver and further benefit the patient experience. Patients are more aware today of how their care is delivered, from waiting times to the caregiver's empathy."

With the explosion in imaging utilization over the last two decades coupled with the emergence of information technology (IT) and digitization in healthcare, patients may feel disconnected from their caregivers and the care process. MR Excellence provides an opportunity to utilize data and IT to identify areas of improvement in the entire imaging workflow.

"The MR Excellence Program and the Imaging Insights dashboards are like a lighthouse that delivers a live view of the MR imaging department, so we can improve performance, optimize system utilization and reduce variability, all which impact the patient experience."

Paolo Sana

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Cardiac MR in patients with CIEDs

By Karl Vigen, PhD, Senior Scientist, and Christopher Francois, MD, Professor, University of Wisconsin Hospital, Madison, WI

MR imaging volume in patients with Cardiovascular Implantable Electronic Devices (CIEDs) is growing due to the adoption of MR-Conditional devices. Modified cardiac protocols can address common artifacts and distortions resulting from the device, battery or other electronic components, while also complying with MR-Conditional device labeling.

MR imaging was historically contraindicated for patients with CIEDs including pacemakers, implantable cardioverter defibrillators (ICDs), and cardiac resynchronization therapy pacemakers and defibrillators (CRT-P/Ds), due to concerns over possible lead heating, device migration and device malfunction. However, recent CIED development has led to devices with improved resistance to environmental electromagnetic interference, and many recent models have MR-Conditional labeling with approval from regulatory agencies such as the FDA.

As more patients are implanted with MR-Conditional devices, our volumes have grown (see Figure 1) to more than 100 in 2018. The adoption of MR-Conditional implants improves access and the use of MR in these patient subgroups.

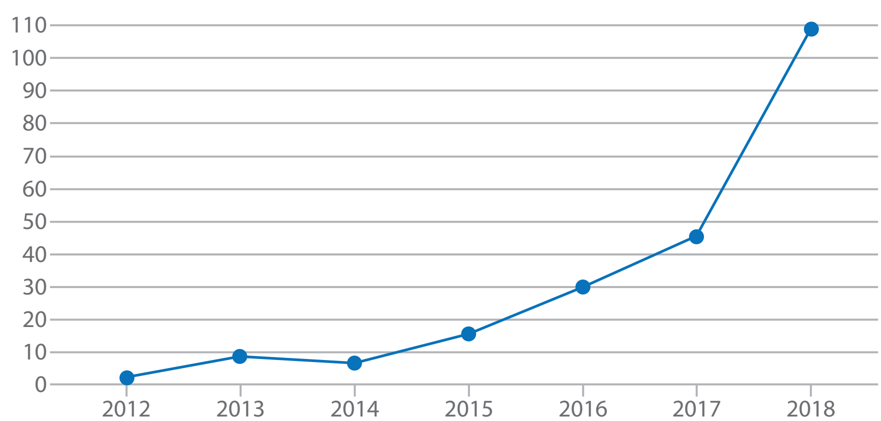

Figure 1. Number of MR exams in patients with MR-Conditional devices, all types (cardiac and non-cardiac) at the University of Wisconsin Hospital.

Due to the location of the CIED generator, most commonly in the left upper chest, distortions in B_0 and B_1 due to the battery and other electronic components can lead to severe artifacts in cardiac MR (CMR), particularly with ICDs and CRT-Ds. Nearly five years ago, our institution developed a modified CMR protocol for use in patients with CIEDs.

Prior to the imaging exam, a cardiac device nurse programs the patient's device to the pacing parameters corresponding to the device's "MRI mode" or another acceptable mode, as determined by the device clinic team. This is generally a setting such that pacing is off, or a backup mode such that the patient's underlying rhythm is maintained. Occasionally, an asynchronous pacing mode can be used, which paces the patient's heart at

Figure 2. (A) Axial FIESTA. (B) Axial Fast SPGR Cine post-contrast. Note the banding artifact in the FIESTA acquisition.

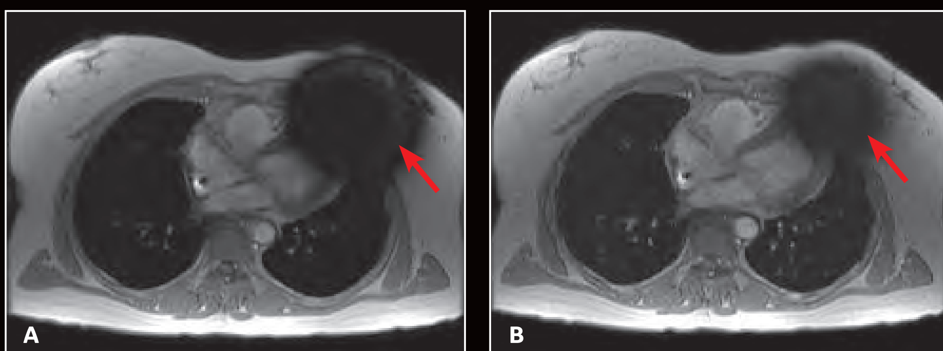

Figure 3. Acquired using Fast SPGR Cine. Comparison of a (A) conventional 8 mm thick/ 0 mm gap slice with a (B) 4 mm thickness and 4 mm spacing to maintain coverage. Note the decrease in artifact with the thinner slice imaging.

a regular rate, and can greatly improve MR image quality compared to an irregular heart rate.

Patient positioning in the MR scanner is similar to exams in patients without devices. The patient is connected to a patient monitoring system, so that the patient's ECG and pulse oximetry information can be monitored throughout the exam. In addition, we attempt to have the patient place their arms over their head, as this can move the device away from the imaging field-of-view (FOV) and reduce the amount of main magnetic field (B_0) modulation near the imaging FOV.

FIESTA imaging sequences can contain banding artifacts due to B_0 field modulations; the artifacts can be particularly troubling due to the intense B_0 modulation caused by the CIED. These artifacts are usually more severe with ICDs compared to pacemakers. By using a Fast SPGR Cine imaging sequence, the banding artifacts can be removed, albeit with a reduction of blood-to-myocardium contrast-to-noise ratio (CNR). Acquiring the short- and long-axis Fast SPGR Cine images following contrast agent administration can improve CNR, and has the additional benefit of decreasing total exam time (since there is normally 10 minutes of waiting following contrast agent administration).[‡] Figure 2 shows a typical image acquired with FIESTA (2A) and post-contrast Fast SPGR Cine (2B) in a patient with an ICD.

Using thinner slices to reduce through-slice dephasing can also help reduce artifact. In Figure 3A, a more conventional 8 mm thick/0 mm gap slice was used with Axial post-contrast Fast SPGR Cine; in Figure 3B, a slice at the same location with 4 mm thickness and 4 mm spacing to maintain coverage with fewer artifacts was utilized. Disadvantages include increased TE with reduced slice thickness and reduced SNR, although the CNR between blood and myocardium can be improved if acquired post-contrast.

For late gadolinium enhanced (LGE)/ myocardial delayed enhancement (MDE) imaging, an inversion pulse with an appropriate TI is used to suppress signal from normal myocardium, highlighting signal from infarcted myocardium. With conventional MDE imaging, B_0 inhomogeneity could cause incomplete inversion and artifactual high signal in normal myocardium could be mistaken for infarction. A new wide-bandwidth adiabatic inversion pulse for MDE (standard in GE's DV26.0 software) allows suppression of myocardial signal without artifactual high signal (see clinical cases). When combined with the Phase-Sensitive Inversion Recovery (PSIR) option, high image quality can be achieved (Figure 4). We do not use the single-shot MDE sequence (SS MDE) at 1.5T for these patients, since this uses a FIESTA readout combined with parallel imaging; the combination is prone to artifactual high late enhancing signal.

‡Drug products should be used in accordance with their approved labeling.
Gadolinium-based contrast agents have not been approved for cardiac use in all regions.

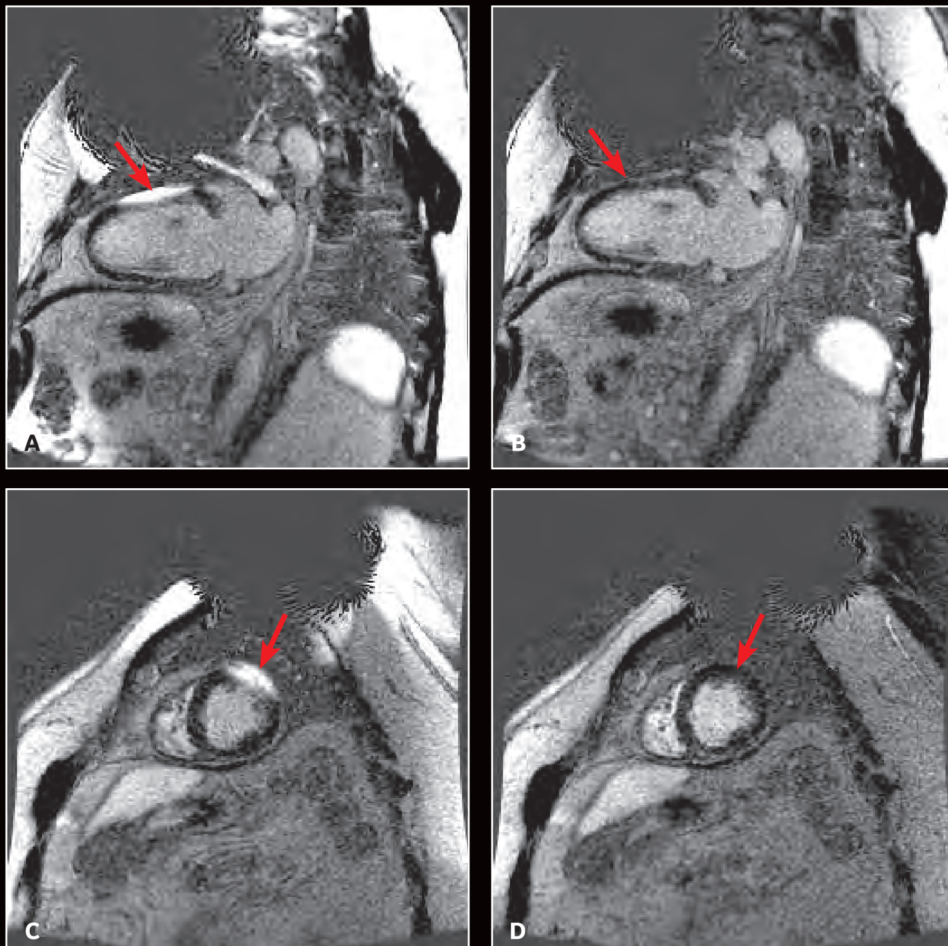

Figure 4. Comparison of (A, C) original inversion vs (B, D) higher broadband inversion, using the PSIR option. Note the improved image quality when improved broadband inversion was utilized.

We image all MR-Conditional CIED patients at 1.5T, with SAR and dB/dT set to Normal Operating Mode, which has a whole body SAR limit of 2.0 W/kg. Recent versions of GE software include a Low SAR mode, allowing the user to specify even lower limits for SAR or B_{1+RMS}. Most MR-Conditional CIEDs specify 2.0 W/kg for SAR at 1.5T; however, those that are MR-Conditional at 3.0T can have lower limits. For example, the Medtronic Advisa DR/SR MRI pacemakers specify maximum B_{1+RMS}=2.8μT for thoracic imaging, which can be easily set in Low SAR mode. The availability of 3.0T imaging combined with low SAR mode is expected to be important if the scan is clinically indicated for 3.0T (e.g., PET/MR) or for institutions without access to a 1.5T system.

Currently, all patients with MR-Conditional CEIDs are scanned on a wide bore 1.5T MR system in our facility, assuming specifications for field strength and maximum spatial gradients of the static field in the MR-Conditional device labeling can be met. We find the wider bore is particularly helpful when imaging patients who cannot easily hold their arms above their head. Additionally, employing rapid sequences may reduce scan times and enhance patient comfort and compliance; however, our institution has not yet evaluated rapid sequences for CMR imaging in patients with MR-Conditional devices.

Recently, GE introduced lightweight AIR Technology™ Coils. While we have not had an opportunity to use the AIR Technology™ Coils for imaging patients with CIEDs, our current experience for cardiac imaging on our 3.0T SIGNA™ Premier systems demonstrate excellent image quality. We anticipate improved patient comfort for these exams, which may facilitate improved compliance for arms-above-head positioning.

Case 1

Patient with a history of dilated cardiomyopathy and worsening ejection fraction; pacing dependent. With MR, the left atrium and left ventricle were shown to be mildly dilated. Global hypokinesis was seen with regional variation specifically with focal hypokinesis/dyskinesis in the mid/apical septal and apical anterior segments. There is curvilinear late gadolinium enhancement consistent with scarring in the basal-anterior septal mid myocardium.

Optima™ MR450w

PARAMETERS

	Sagittal short axis Fast SPGR Cine	*Axial long axis Fast SPGR Cine*	*Sagittal short axis PS MDE*	*Coronal and Axial long axis PS MDE*
TR (ms):	6.3	6.3	8.2	7.9
TE (ms):	2.6	2.6	3.9	3.8
FOV (cm):	38 x 38	38 x 29.3	38 x 26.6	38 x 30.4
Slice thickness (mm):	6	6	6	5
Frequency:	256	256	224	200
Phase:	160	160	192	192
NEX:	1	1	1	1
Scan time (min):	1:30 (12 slices)	0:25 (sec.) (3 slices)	1:48 (12 slices)	0:42 (sec.) (4 slices)

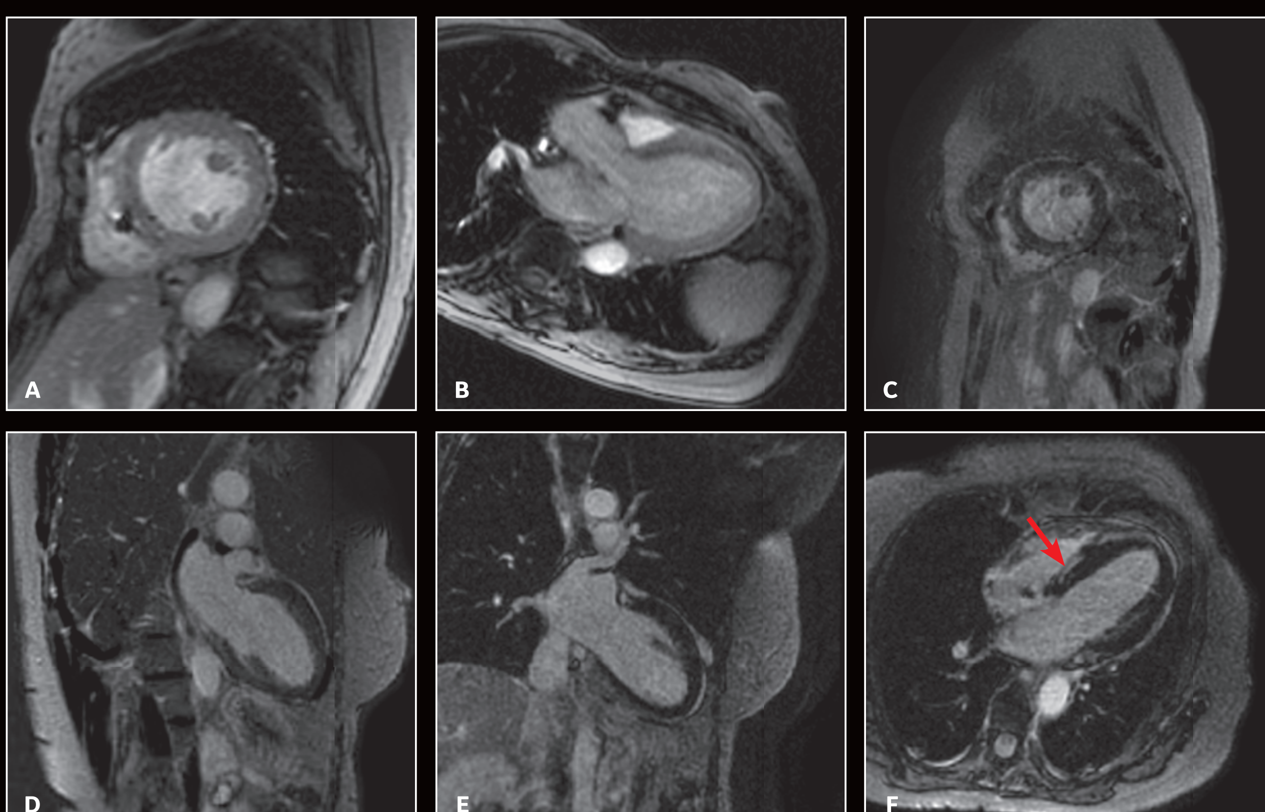

Figure 5. (A) Short axis Fast SPGR Cine; (B) long axis Fast SPGR Cine; (C) short axis MDE (arrow); (D-F) long axis MDE.

Case 2

Patient with a history of ventricular tachycardia with possible left ventricular thrombus. MR shows enlarged left ventricle, with global hypokinesis with dyskinesis in the apical anterior wall and true apex. Thrombus is seen in the apex, with a thin rim of increased enhancement at the edges of the thrombus. There is subendocardial to transmural enhancement in the apex. Ⓢ

Optima™ MR450w

PARAMETERS			
	Coronal short axis Fast SPGR Cine	*Axial long axis Fast SPGR Cine*	*Long axis PS MDE*
TR (ms):	5.3	5.3	5.9
TE (ms):	2.4	2.4	2.8
FOV (cm):	40	40	40
Slice thickness (mm):	6	6	6
Frequency:	192	192	192
Phase:	160	160	192
NEX:	1	1	1
Scan time (min):	1:21 (12 slices)	0:20 (sec.) (3 slices)	0:49 (sec.) (3 slices)

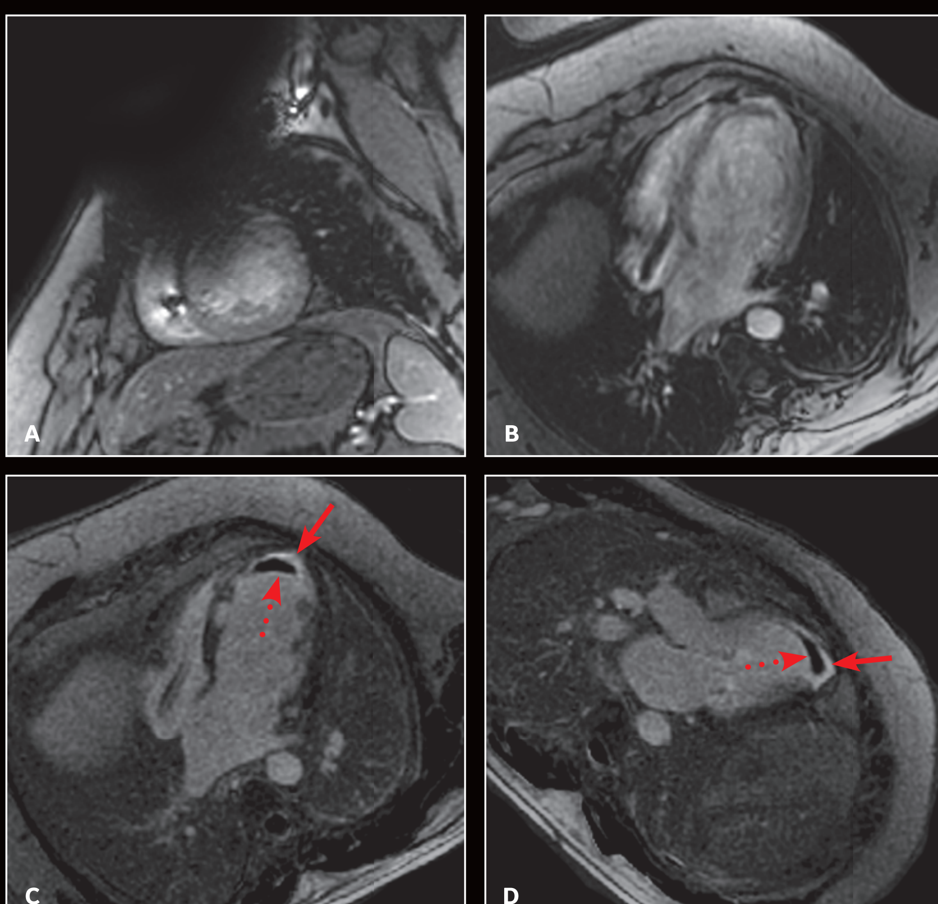

Figure 6. (A) Short axis Fast SPGR Cine; (B) long axis Fast SPGR Cine; (C-D) phase-sensitive long axis LGE.

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Body imaging with AIR Technology Anterior Array and Posterior Array

Submitted by Quirónsalud Madrid University Hospital

Fetal imaging

By Manuel Recio Rodríguez, MD, Associate Chief of Diagnostic Imaging Department

With the AIR Technology™‡ Anterior Array (AA), we can achieve good signal penetration for fetal imaging. This enables us to obtain high-quality images of the fetal brain with short acquisition times using T2 and DWI sequences.

38-year-old pregnant woman; fetus with hydrocephalus.

Coil:	AIR Technology™ AA
Parameters:	
T2 SSFSE in three planes:	- Sagittal: 0.7 x 0.7 x 3 mm, 1:00 min. - Coronal/Axial: 0.7 x 0.7 x 2.5 mm, 1:22 min.
DWI, b800:	- Axial: 2.8 x 2.8 x 2.5 mm, 0:50 sec.

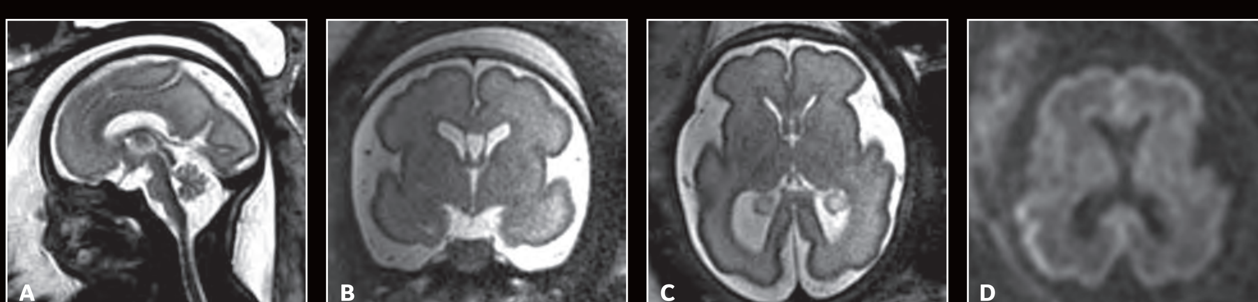

Figure 1. AIR Technology™ AA provides excellent signal penetration for high-quality images. (A) Sagittal T2 SSFSE; (B) Coronal T2 SSFSE; (C) Axial T2 SSFSE; and (D) Axial DWI b800.

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Abdominal imaging

By Vicente Martinez de Vega, MD, Chief of Diagnostic Imaging Department

Abdominal imaging with the AIR Technology™ Coils is better than we expected, particularly the coverage, signal homogeneity, high spatial resolution and scanning speed. We were also able to achieve short acquisition times and homogenous fat suppression. In this particular case, a thickening of the terminal ileum can be noticed in a very short segment, which is consistent with Crohn's disease.

48-year-old male with Crohn's disease.

Coils:	AIR Technology™ AA and Posterior Array (PA)
Parameters:	
T2 SSFSE in two planes with and without FatSat:	- Axial: 0.8 x 1 x 4 mm, 0:52 sec. - Axial w/FatSat: 0.9 x 0.9 x 4 mm, 0:54 sec. - Coronal: 1 x 1.25 x 4 mm, 0:38 sec.
Axial DWI:	b1000, 2.9 x 1.2 x 5 mm
T1 LAVA ASPIR in two planes:	- Axial 1 x 1.25 x 2.4 mm, 0:24 sec. - Coronal: 1 x 1.25 x 3 mm, 0:19 sec.
Coronal T1 DISCO:	1 x 1.6 x 2 mm, 7 sec./phase
Coronal T2 FIESTA dynamic:	1 x 1 x 3 mm, 0:54 sec.

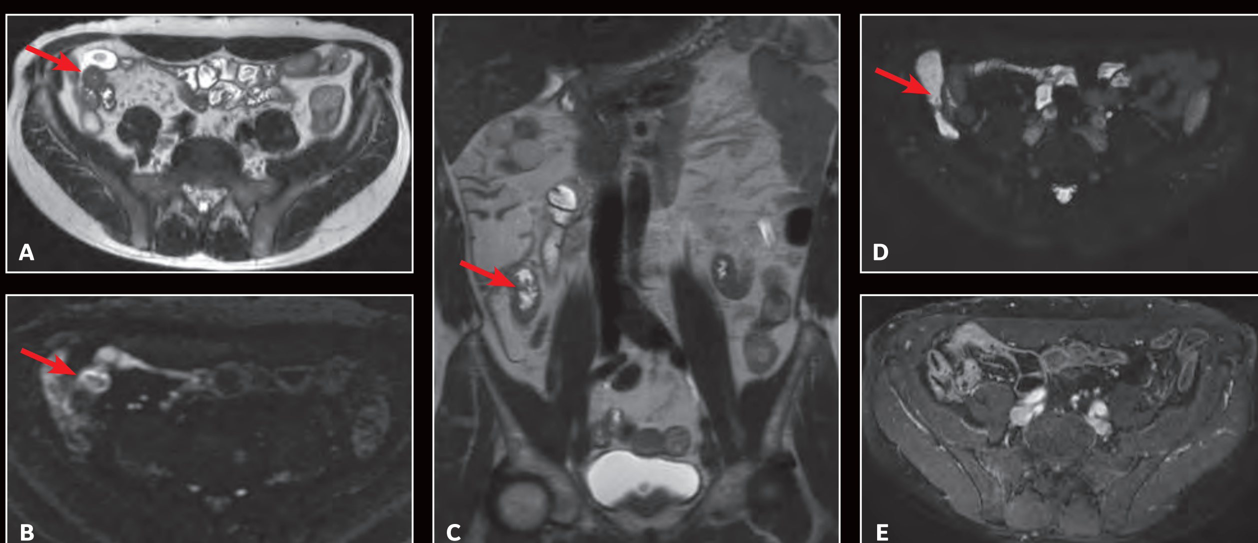

Figure 2. AIR Technology™ AA and PA Coils for abdominal imaging deliver better than expected coverage, signal homogeneity, high spatial resolution and homogeneous fat suppression. A thickening of the terminal ileum (red arrows) is consistent with Crohn's disease. (A) Axial T2 SSFSE; (B) Axial DWI b1000; (C) Coronal T2 SSFSE; (D) Axial T2 SSFSE FatSat; and (E) Axial T1 LAVA ASPIR.

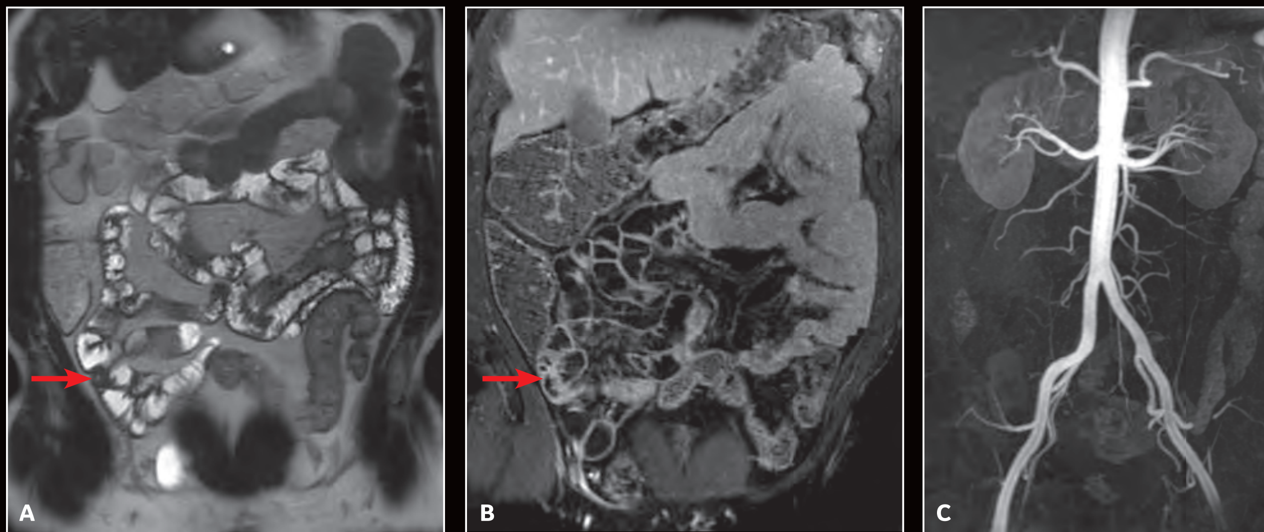

Figure 3. A thickening of the terminal ileum (red arrows) is consistent with Crohn's disease. (A) Coronal T2 SSFSE; (B) Coronal T1 LAVA ASPIR; and (C) MIP from DISCO, arterial phase.

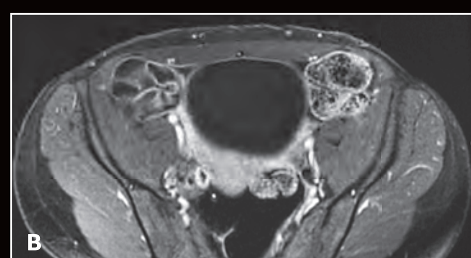

Figure 4. Same patient as Figure 3. (A) Coronal T2 FIESTA and (B) Axial T1 LAVA ASPIR.

Prostate imaging

By Manuel Recio Rodríguez, MD, Associate Chief of Diagnostic Imaging Department

Prostate MR is growing in use and referrals in our institution. However, in order to clearly depict the cancer to determine the extent of disease, it is necessary to obtain T2 sequences with high spatial resolution. Also, T2 Cube images can be used to merge with ultrasound to assist in performing targeted biopsies. In this particular case, a lesion with high signal in the T2-weighted sequence in the central prostate can be seen. There is no enhancement in the dynamic sequence and restricted diffusion is consistent with a prostate abscess. Dynamic acquisition with DISCO LAVA provides high spatial and temporal resolution (4.5 seconds per phase) and the diffusion imaging is very high quality. S

71-year-old male with prostate cystic adenoma.

Coils:	AIR Technology™ AA and PA
Parameters:	
Axial T2 FSE:	3 x 0.4 x 0.7 mm, 4:47 min.
Axial T2 Cube:	0.5 x 0.8 x 0.8 mm, 5:31 min.
FOCUS DWI:	b800, 3 x 2 x 2 mm MAGiC DWI: b1500
Axial DISCO LAVA:	1.5 x 1 x 1 mm, 4.5 sec./phase

Figure 5. AIR Technology™ AA and PA provide high spatial resolution in T2 sequences, which improves visualization of the cancerous lesion for staging. Note the lesion with a high signal in the central prostate. (A) Axial T2 and (B) Axial T2 Cube.

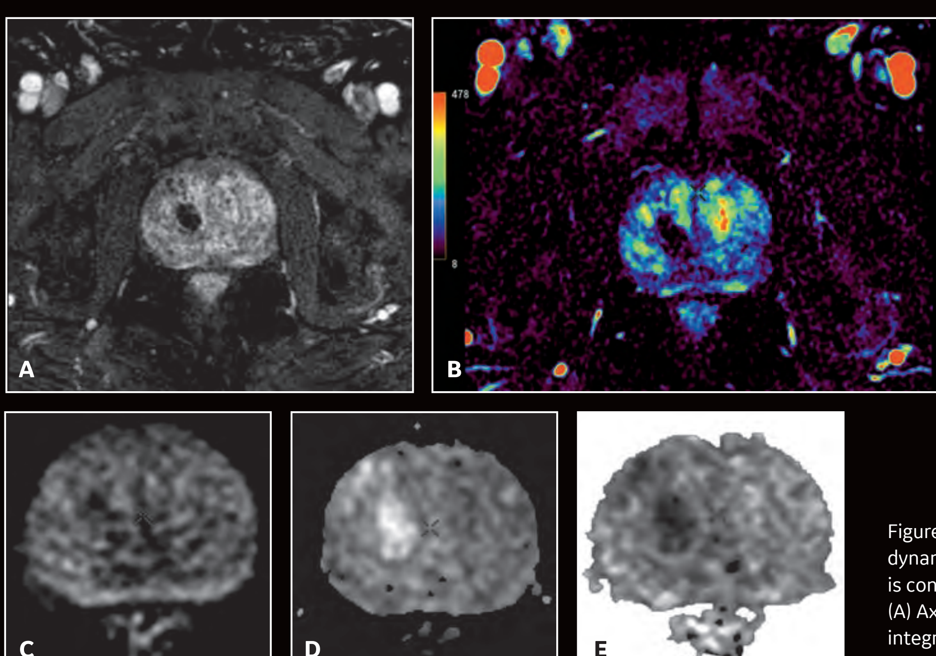

Figure 6. There is no enhancement in the dynamic sequence and restricted diffusion is consistent with a prostate abscess. (A) Axial DISCO LAVA; (B) enhancement integral map; (C) Axial DWI FOCUS b800; (D) ADC map; and (E) MAGiC DWI b1500.

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Neuro imaging with 48-channel Head Coil

By Krisztina Baráth, MD, neuroradiologist, and Brigitte Trudel, RT(R)(MR), MRI Chief Technologist, RNR Institute of Radiology and Neuroradiology at Glattzentrum

When scanning with the new 48-channel Head Coil on the SIGNA™ Pioneer 3.0T MR system, routine neuro acquisitions show significantly higher signal-to-noise ratio (SNR) compared to prior acquisitions with the conventional Head Neck Unit (HNU) coil.

With the embedded AIR Technology™ element design, we can observe a very homogenous signal distribution over the whole field-of-view without any signal drop in the center of the brain. In our experience, we know this is not the case for every dedicated neuro coil available on the market.

Additionally, the coverage of the coil in the z-direction gives us the versatility to easily scan the brain and cervical spine for multiple sclerosis as well as carotid MRA studies.

The 48-channel Head Coil has an adaptable design with an additional 3 cm expansion to gain more room for very large-sized heads and necks. It also helps reduce the patient feeling confined or having their nose in contact with the front of the coil. The coil is compatible with the comfort tilt device, which is very important when scanning elderly patients suffering from kyphosis because it helps them lie comfortably on the table. It is essential for our dementia protocols that the patient not move during scanning due to discomfort.

By combining the advantage of extra SNR with high ARC factors and new acceleration techniques, such as HyperSense and HyperBand, we are able to decrease significantly our total examination time for neuro protocols by 25% while maintaining or even increasing image quality and spatial resolution.

The 48-channel Head Coil is a real asset for us as a neuroradiological institute and it further extends the clinical benefits of a powerful 3.0T MR system such as the SIGNA™ Pioneer.

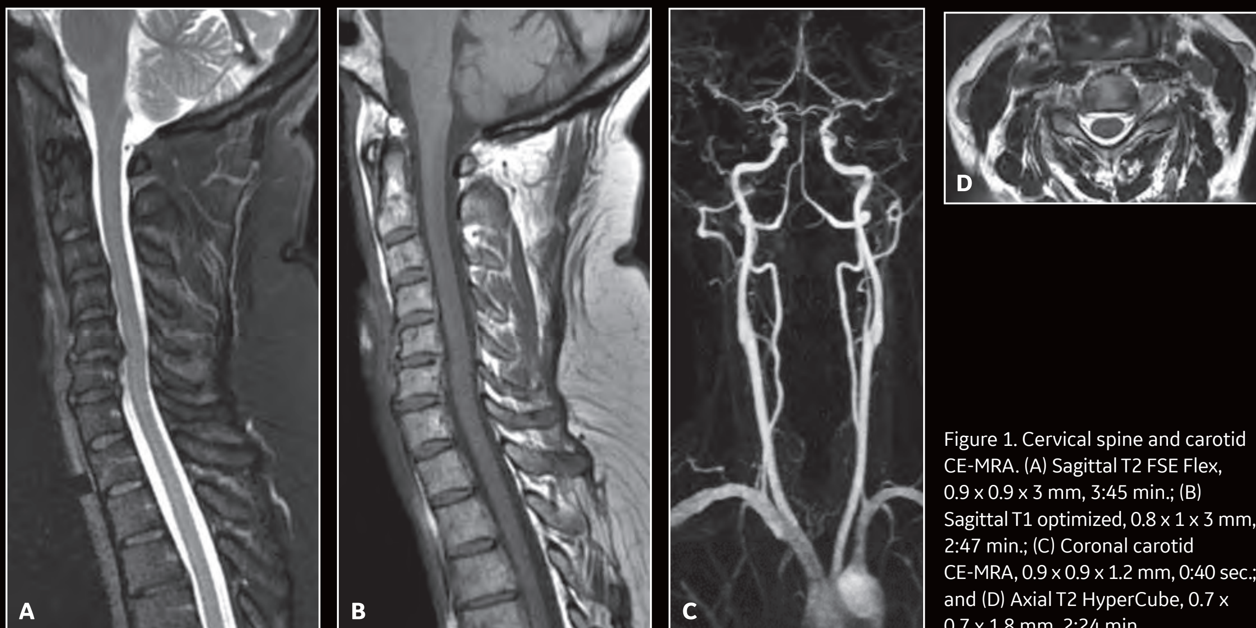

Figure 1. Cervical spine and carotid CE-MRA. (A) Sagittal T2 FSE Flex, 0.9 x 0.9 x 3 mm, 3:45 min.; (B) Sagittal T1 optimized, 0.8 x 1 x 3 mm, 2:47 min.; (C) Coronal carotid CE-MRA, 0.9 x 0.9 x 1.2 mm, 0:40 sec.; and (D) Axial T2 HyperCube, 0.7 x 0.7 x 1.8 mm, 2:24 min.

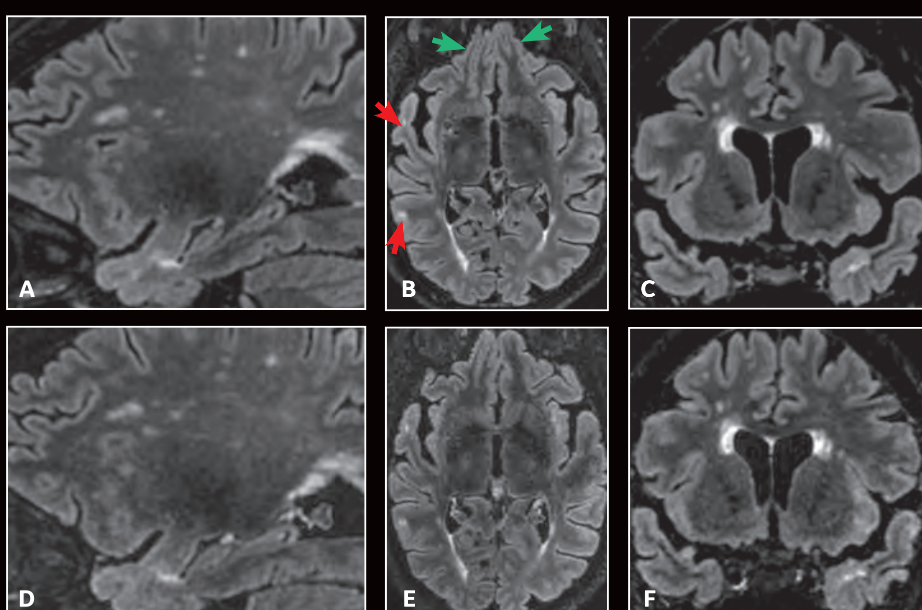

Figure 2. Patient with multiple sclerosis. Higher SNR with the 48-channel Head Coil enables better gray matter delineation (green arrows) and enhanced lesion depiction (red arrows). (A-C) 48-channel Head Coil, Sagittal Cube FLAIR HyperSense, 1 x 1.1 x 1.2 mm, 3:30 min.; and (D-F) conventional HNU, Sagittal Cube FLAIR HyperSense, 1 x 1.1 x 1.2 mm, 3:45 min.

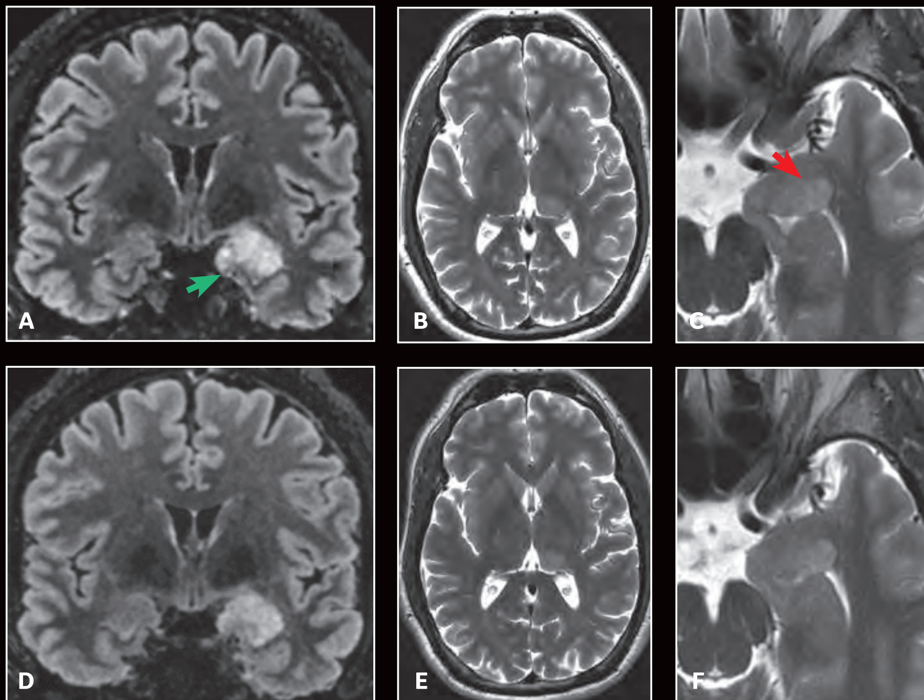

Figure 3. Patient with low-grade glioma. Higher SNR with the (A-C) 48-channel Head Coil enables better in-plane resolution (green arrow) and enhanced lesion depiction (red arrow) than (D-F) images acquired with conventional HNU. (A, D) Cube FLAIR with HyperSense, 1 x 1.1 x 1.2 mm, 3:38 min. with 48-channel Head Coil and 3:45 min. with conventional HNU; (B, C, E, F) Axial T2 PROPELLER, 0.5 x 0.5 x 3 mm, 2:10 min. with 48-channel Head Coil and 0.6 x 0.6 x 3 mm, 2:23 min. with conventional HNU.

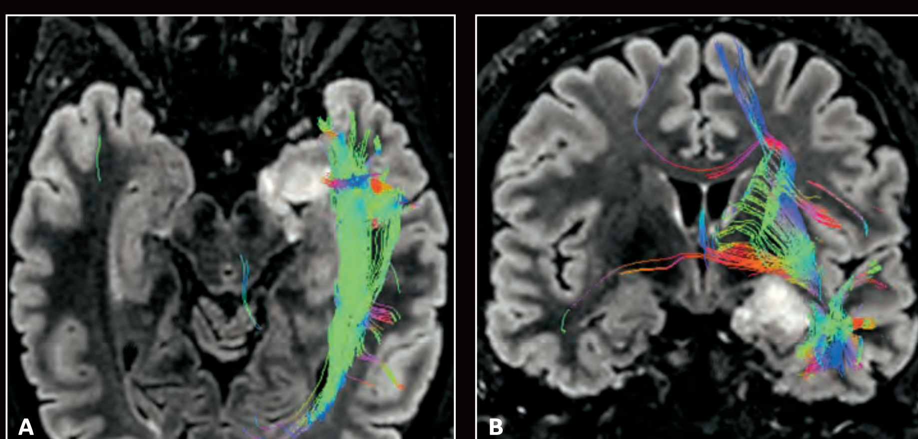

Figure 4. Patient with low-grade glioma. (A, B) DTI HyperBand with 32 directions, 2.2 x 1.8 x 4 mm, 3:43 min.

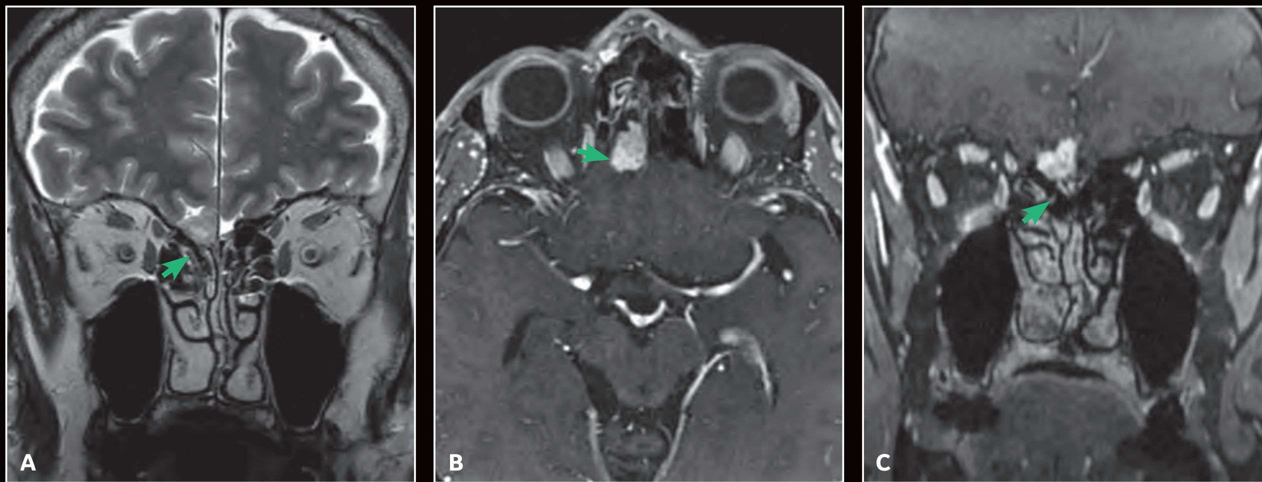

Figure 5. Patient with meningioma scanned with the 48-channel Head Coil. (A) Coronal T2, 0.5 x 0.6 x 3 mm, 2:15 min.; (B) Axial LAVA ASPIR post contrast, 0.8 x 0.8 x 1 mm, 3:50 min. with (C) Coronal reformat.

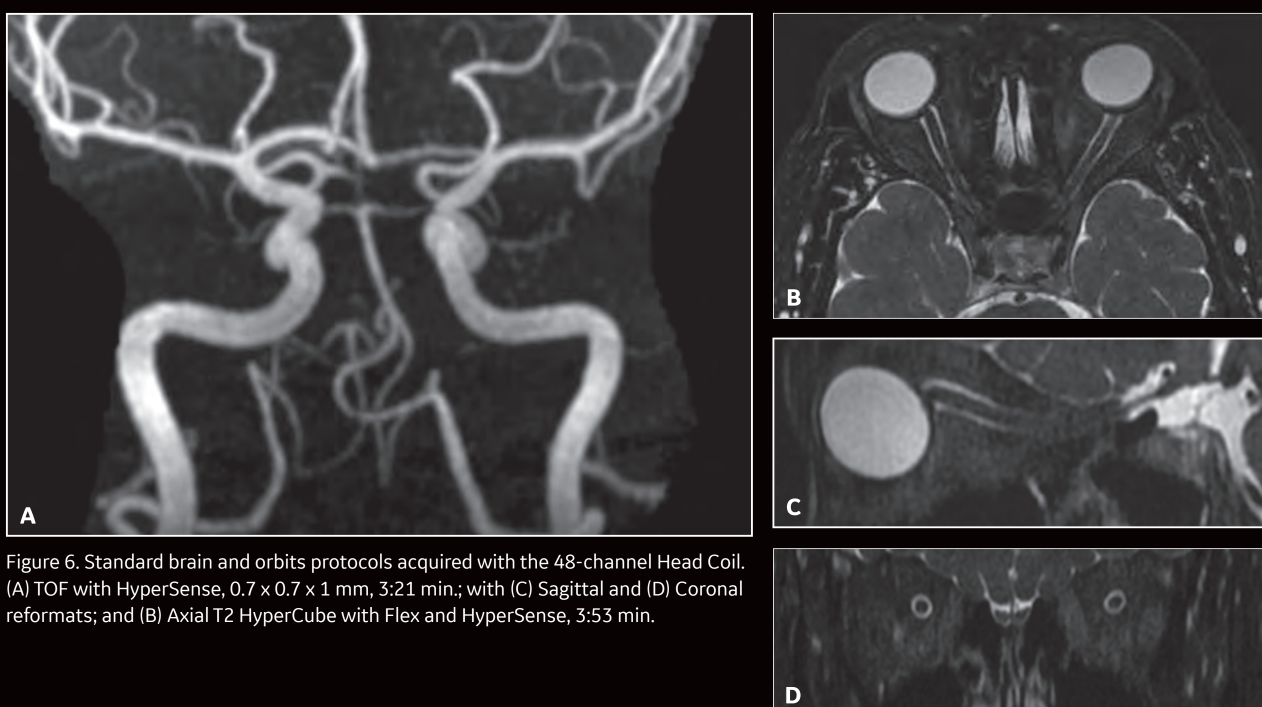

Figure 6. Standard brain and orbits protocols acquired with the 48-channel Head Coil. (A) TOF with HyperSense, 0.7 x 0.7 x 1 mm, 3:21 min.; with (C) Sagittal and (D) Coronal reformats; and (B) Axial T2 HyperCube with Flex and HyperSense, 3:53 min.

Diffusion imaging with AIR Technology Suite

Submitted by Kawasaki Saiwai Hospital

Case 1

A 59-year-old female with loss of consciousness. Prior history includes gall bladder stone and cholecystitis.

MR findings

Patient has multiple infarction. Micro infarction was not clearly visualized in conventional DWI sequence. However, MUSE enabled high-resolution DWI that enabled depiction of micro infarction in the gray matter.

59-year-old female.

Coil:	48-channel Head Coil
Parameters:	
DWI, b1000:	0.9 x 1.9 x 5 mm
MUSE, b1000:	0.8 x 0.9 x 5 mm

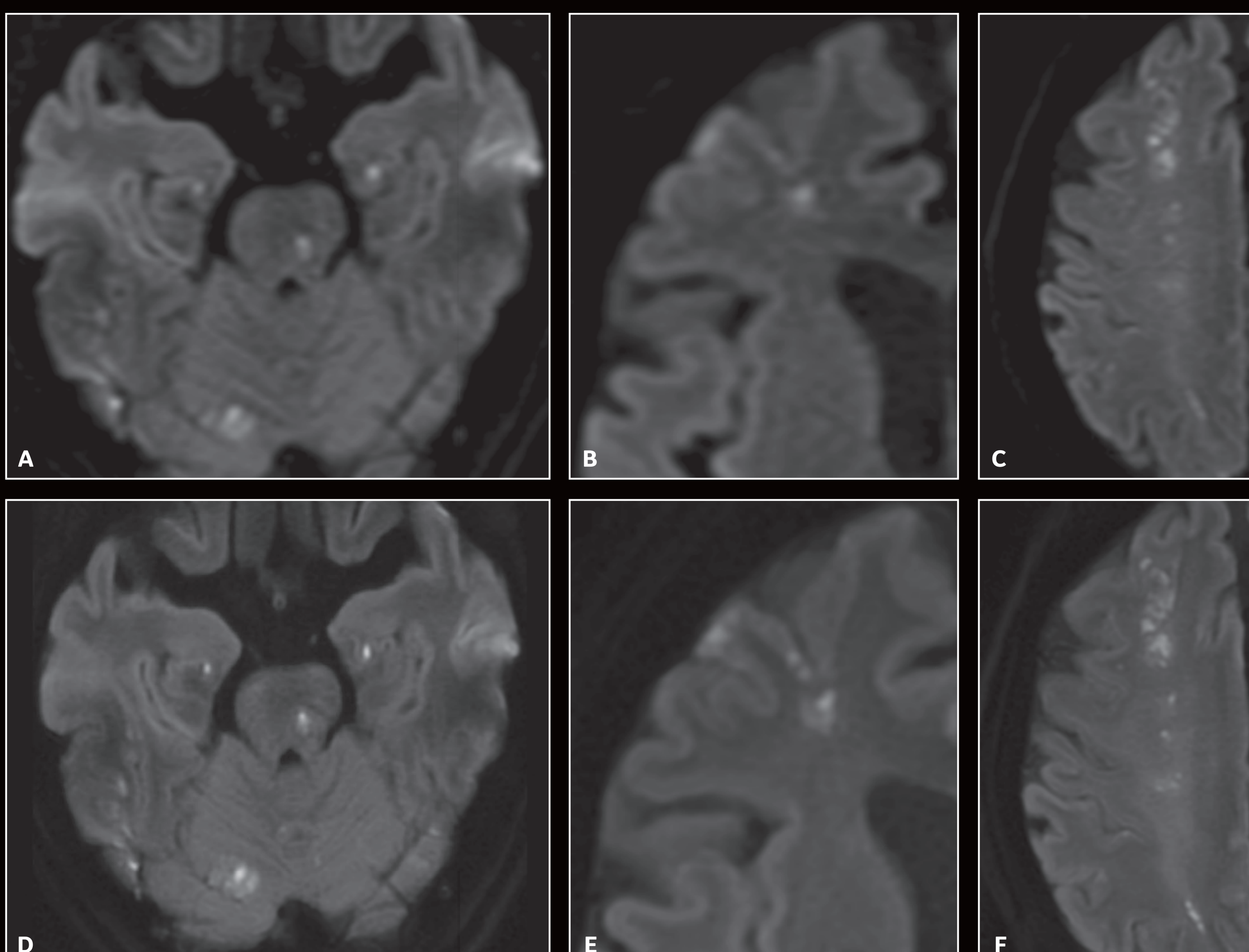

Figure 1. With the improvement in resolution using MUSE, there is clear depiction of the infarct in the gray matter compared to the conventional sequence. (A-C) Conventional DWI, b1000; (D-F) MUSE, b1000.

Case 2

A 46-year-old male presenting with fever of unknown origin and suspected infection after aortic stent replacement surgery.

MR findings

T2 SSFSE and T2 STIR PROPELLER MB confirmed abscess formation in the left upper lung lobe without having to reposition the coil. High signal DWI confirmed location. Whole-body Coronal DWI was acquired in two stations. The AIR Technology™‡ Anterior Array (AA) allows higher parallel imaging factors, enabling low-distortion DWI even in cases with a large field-of-view. Ⓢ

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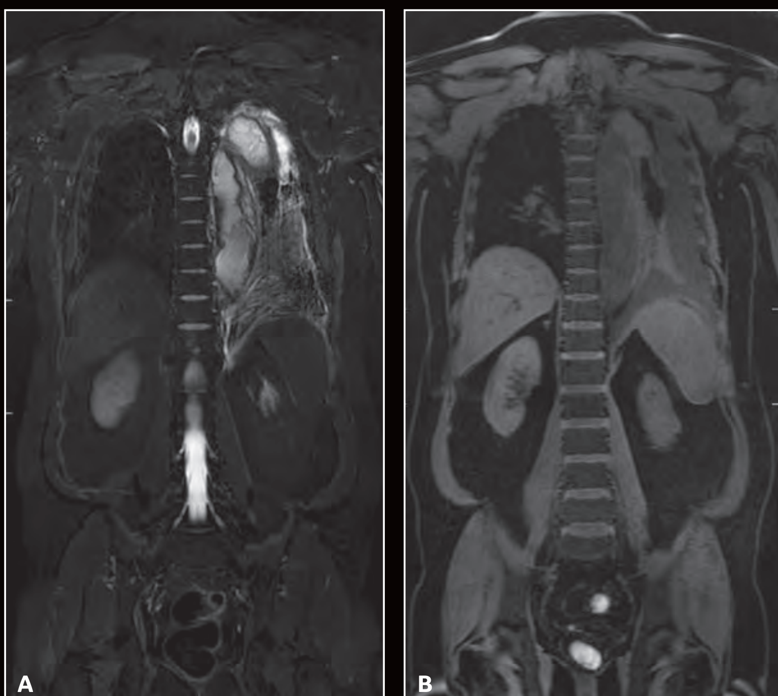
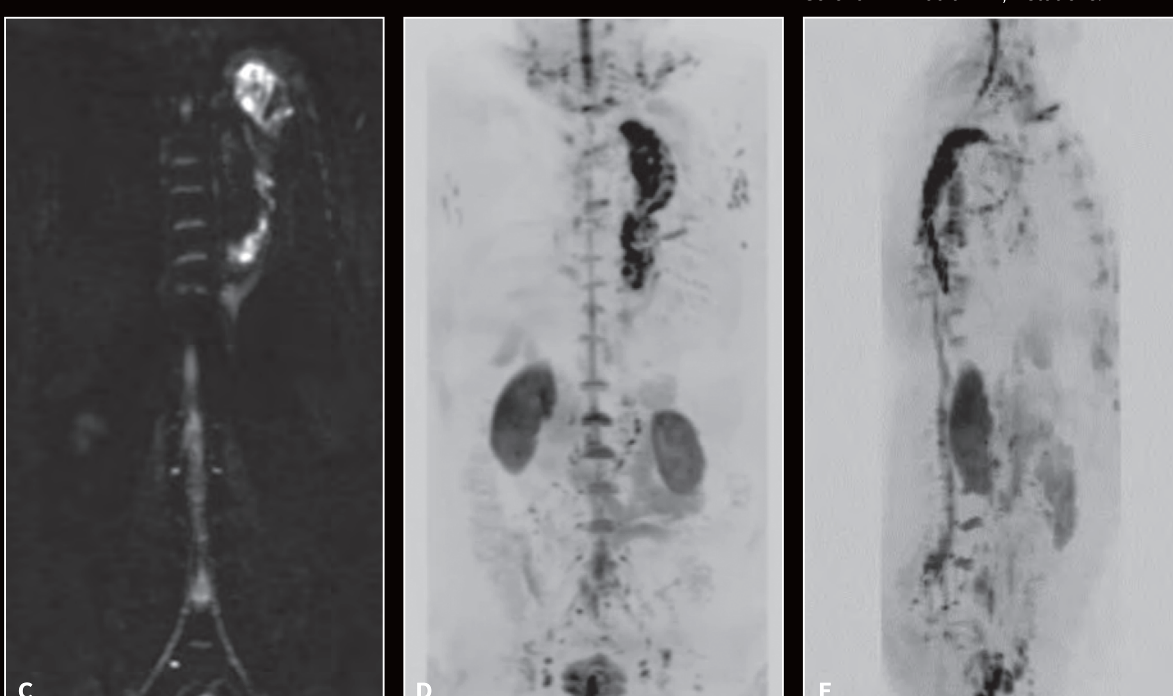


46-year-old male.

Coil:	AIR Technology™ AA
Parameters:	
T2 STIR PROPELLER MB:	1.6 x 1.6 x 5 mm ARC factor of 3 3:49 min.
T2-weighted SSFSE:	1.3 x 2.1 x 5 mm 1:10 min.
Whole-body DWI, b800:	2 station Coronal DWI, 1.8 x 4.2 x 5 mm Acc 2.0/4.0 4:00 min.

Figure 2. (A) Coronal T2w STIR PROPELLER MB; (B) Coronal LAVA; (C) Coronal DW-EPI, 2 stations; (D) whole-body DWI, radial MIP; (E) whole-body Coronal DWI radial MIP, 2 stations.



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Free-breathing liver imaging using DISCO with Auto Navigator

By Claire Moisson, RT(R)(MR), and Stephanie Sellier, RT(R)(MR), Lead Technologist, Medipole de Savoie

MR imaging is routinely used for non-invasively evaluating the liver. Improvements in both diffusion-weighted sequences and hepatocyte-specific contrast agents have improved the detection of both primary and secondary (metastatic) lesions.

However, many patients are unable to perform breath-holds due to the extent of their liver disease and side effects of cancer treatments. This inability to hold their breath for approximately 15 seconds can impact image quality and in some cases render the MR study insufficient for radiologist diagnosis and evaluation of patient treatment.

Recent advances in MR imaging sequences offer a free-breathing option for patients who cannot hold their breath, even though they have a regular, stable breathing pattern, capturing high quality images without a breath-hold. Auto Navigator is a free-breathing technique that combats respiratory motion and includes an automatic tracker placement for enhanced workflow. More importantly, it is compatible with all the typical sequences used for liver imaging, including T2 PROPELLER MB, FSE and DWI, as well as the critical dynamic T1 sequences, such as LAVA, LAVA Flex and DISCO.

The navigator tracker is automatically placed over the right hemidiaphragm and synchronizes with the patient's breathing pattern to reduce respiratory ghosting artifacts. Acceptance window and threshold levels can be adjusted during the acquisition, which helps eliminate failures due to changes in the patient's respiratory cycle, especially as the patient begins to relax in the MR bore.

Combining Auto Navigator with DISCO delivers excellent image quality with a free-breathing, dynamic scan without sacrificing resolution.

SIGNA™ Artist

PARAMETERS	*Axial DWI*	*Axial LAVA Flex, breath-hold*	*Axial LAVA Flex, Navigated*	*DISCO Flex DCE*
TR (ms):	5217	6.2	6.2	6.4
TE (ms):	71.7	3.1	3.1	3.1
FOV (cm):	44	42	42	42
Slice thickness (mm):	5 / 0.5	4.4	4.4	4.4
Frequency:	112	320	320	320
Phase:	128	224	224	224
NEX:	b50 = 4; b1000 = 12	1	1	1
Zip:		2	2	2
Scan time (min):	3:18	0:15 (sec.)	0:45 (sec.)	5:34
Options/other:	b50, b1000 RTr with ADC map			6 phases view shared (14 sec/phase) + 6 phases delayed non-view shared *k*-space (40 sec/phase)

Patient history

A 70-year-old man was referred to MR for evaluation of hepatocellular carcinoma (HCC) after surgery, targeted therapy and biliary duct prosthesis.

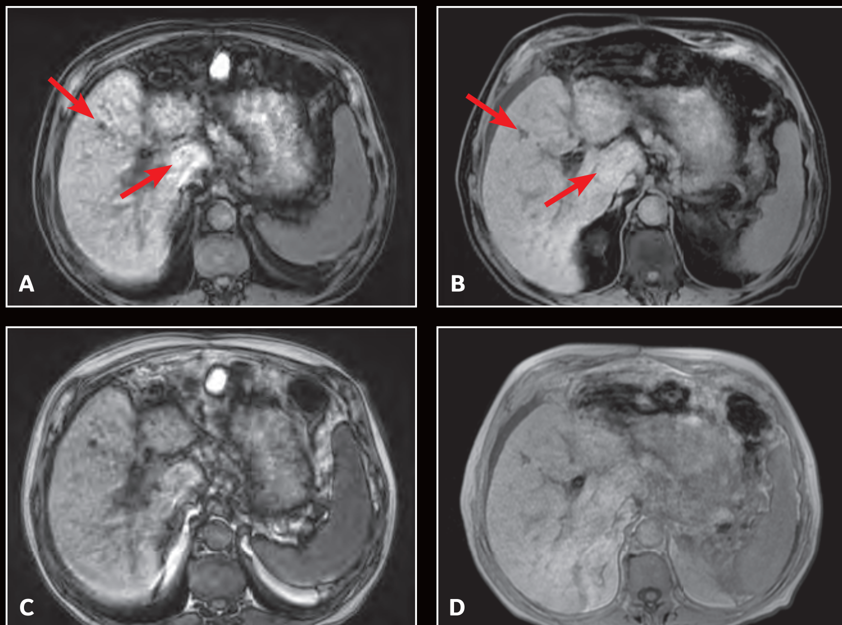


Figure 1. (A, C) LAVA Flex breath-hold where the patient was unsuccessful holding their breath; (B, D) free-breathing LAVA Flex with Auto Navigator made the difference for patient comfort as well as quality.

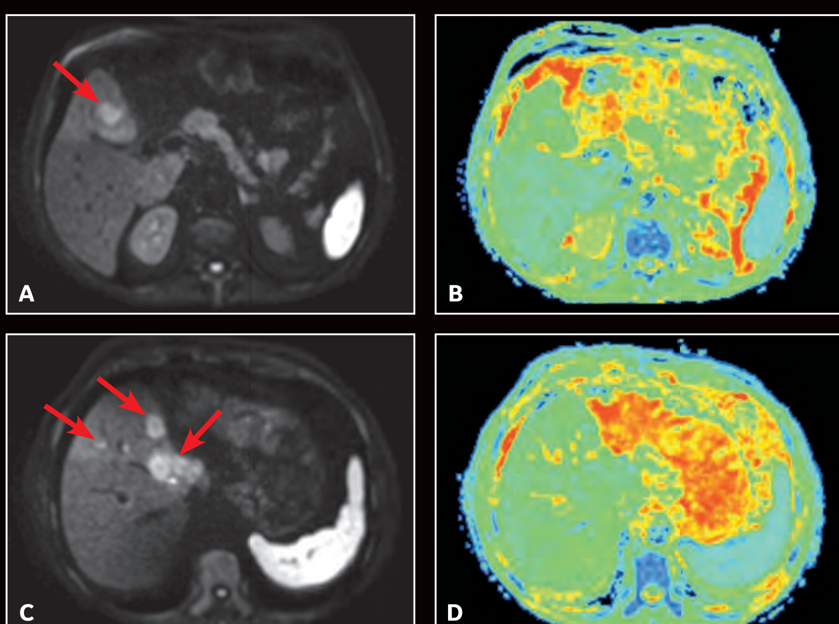


Figure 2. DWI at high b-values delivers a high signal that enables the visualization of new lesions on the hepatectomy side and near the hepatic hilum (red arrows). Different slices from the (A, C) DWI b50-1000 RTr with (B, D) ADC Maps, 3.9 x 3.4 x 5 mm, 3:18 min.

Procedure

Axial LAVA Flex with Auto Navigator replaced a breath-hold sequence because the patient could not hold his breath longer than seven seconds. Free-breathing DISCO with Auto Navigator was also employed to provide high temporal and high spatial resolution. For the dynamic T1, DISCO captured six view-shared arterial phases at 14 seconds per phase and six phases delayed, non-view shared at 46 seconds.

DWI with high b-values may help provide additional information for the evaluation of lesions while the SIGNA™ Artist Total Digital Imaging (TDI) provided adequate signal-to-noise ratio (SNR).

MR findings

Patient had an increase in unresectable HCC lesions despite targeted therapy. Biliary duct dilatation was also noted despite prosthesis.

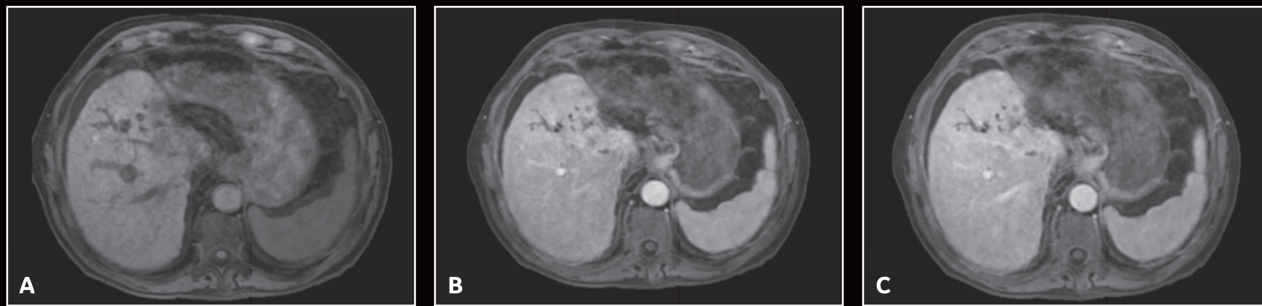


Figure 3. Free-breathing DISCO Flex with Auto Navigator, 1.3 x 1.9 x 4.4, Zip 2, 6 phases view-shared *k*-space (14 sec per phase) + 6 phases full non-view shared *k*-space (46 sec. per phase), in 5:34 min. (A) Phase 0; (B) phase 2 @ 28 sec. (arterial); (C) phase 4 @ 60 sec. (venous).

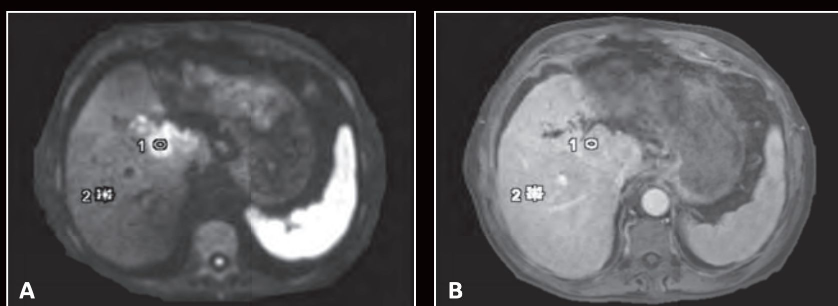
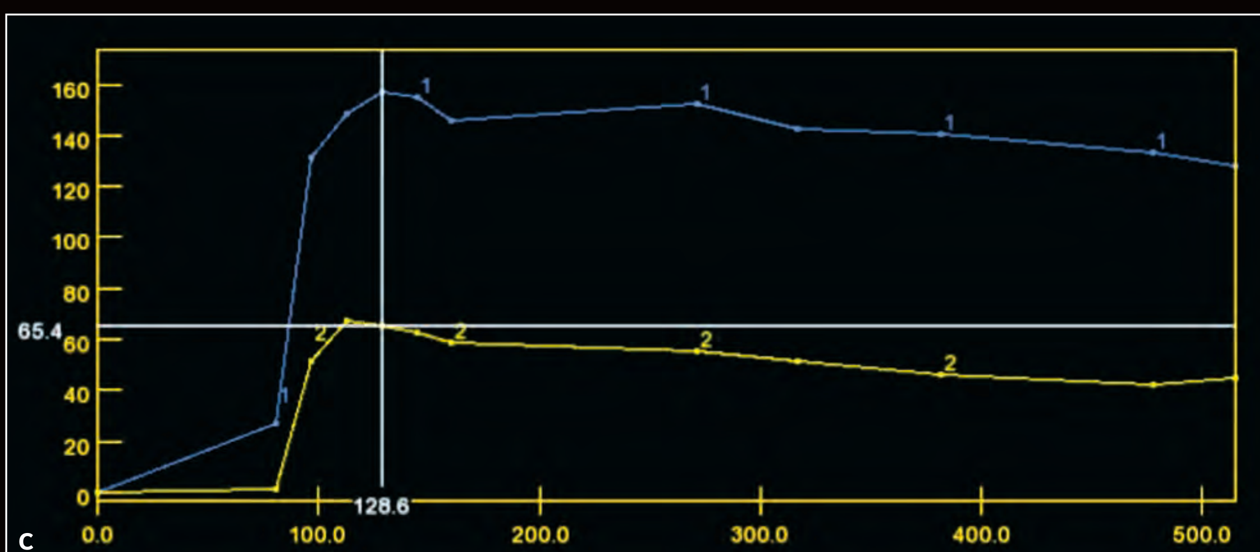


Figure 4. Contrast enhancement of DISCO with Auto Navigator. (A) b1000 and (B) phase 5; (C) ROI 1 = HCC (blue line), ROI 2 = normal liver (yellow line).



Discussion

Without the availability of the Auto Navigator free-breathing protocol, the exam quality would have been insufficient for the radiologist to evaluate patient treatment and detect the new lesions due to the patient's poor breathing pattern and inability to hold their breath. DISCO with Auto Navigator allowed the radiologist to examine hepatic contrast enhancement with high-resolution images (2.2 mm, 320 x 224 matrix, two arterial phases, three venous phases and late enhancement to 5 minutes). Additionally, TDI enabled high signal and high-resolution imaging so we could acquire DWI with a b-value of 1000, 5 mm slice thickness and good SNR.

DISCO with Auto Navigator delivers simplicity of prescription, high spatial resolution and good temporal resolution allowing contrast enhancement analysis on arterial, portal and late phases. DISCO Flex is easy to use and minimizes the technologist's concern regarding enhancement timing. The addition of Auto Navigator and respiratory trigger offer a comprehensive free-breathing protocol that provides images without breathing artifacts for high-quality abdominal imaging.

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Free-breathing navigator-echo triggered diffusion-weighted imaging in the evaluation of hepatobiliary disease

By David Bowden FRCR, Consultant Hepatobiliary & GI Radiologist, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust

Introduction

Increasing demands are made upon MR in the workup of patients with hepatobiliary disease. This is especially true in the evaluation of those with cholangiopathies in which high-quality imaging is critical for the initial disease diagnosis and also in surveillance imaging for the development of malignancy. In addition, there has been continued expansion of treatment options available to patients with primary and secondary hepatic malignancies previously considered untreatable. Surgical resection and locoregional therapies such as radiofrequency ablation, transarterial embolization/chemoembolization (TAE/TACE), radioembolization, hepatic-arterial infusion pump-delivered therapy and external beam radiotherapy are all currently available treatment strategies. While traditionally colorectal metastases have been targeted for therapy, other tumor types are increasingly being considered for more aggressive intervention.

Given the high cost and potential of associated toxicity to normal tissues and organs of many cancer treatment options, accurate identification and characterization of hepatobiliary lesions is critical. Patients listed for transplantation for chronic liver disease, including those with cholangiopathies, require optimal imaging because the identification of a malignancy may ultimately preclude transplantation. Of proven importance is diffusion-weighted imaging (DWI) due to its sensitivity for detecting lesions and, in some cases, its utility in characterizing them.[1] Furthermore, in patients unable to undergo contrast-enhanced MR imaging due to renal dysfunction, DWI is of even greater importance for lesion detection.

Several techniques exist for DWI evaluation of the liver, including breath-hold, free-breathing, respiratory and navigator-echo triggered acquisitions.[2] While breath-hold DWI has the advantage of speed of acquisition, disadvantages include inferior signal-to-noise ratio (SNR), which is particularly pronounced at high b-values and necessitates thicker slice partitions and reduced spatial resolution. This results in inferior lesion-to-liver contrast-to-noise ratios (CNR) and a reliance on the patient's ability to breath-hold for adequate periods of time.[3] In addition, signal loss secondary to susceptibility artifact and motion is more pronounced, in particular within the left liver where cardiac pulsation often markedly compromises image quality.[3]

Navigator-echo triggered DWI can track diaphragmatic motion during free-breathing and subsequently trigger data acquisition in quiescent periods of the respiratory cycle.[3] Given the importance of this sequence, this technique has superseded breath-hold DWI at our institution and has resulted in increased confidence in lesion detection and repeatability. The method is particularly applicable within the left liver to mitigate the effects of cardiac motion and within the most superior segments on the right where the proximity of lung parenchyma often results in image degradation. The resultant high resolution and relative insensitivity to motion artifact has also, on occasion, led to the detection of extrahepatic disease that would otherwise almost certainly go undetected with MR.

Case 1

Patient history

A 65-year-old man with a history of recent removal of a malignant melanoma from the scalp. CT staging demonstrated an indeterminate liver lesion within segment 5, requiring further characterization. If solitary, the patient was to be considered for radiofrequency ablation or resection.

Technique

Standard imaging protocol included navigator-echo triggered DWI using b-values of 50 and 600 in addition to MAGiC DWI (synthetic DWI), a sequence allowing the calculation of additional high b-values without separate acquisitions. This approach reduces scan time and delivers excellent image sharpness and SNR at the synthetically calculated high b-values.

Optima™ MR450w

PARAMETERS

	DWI	*T1 LAVA Flex*
TR (ms):	7056	6.7
TE (ms):	62	3.2
FOV (cm):	38 x38	38 x 38
Slice thickness (mm):	6	4.4
Frequency:	80	320
Phase:	128	224
NEX:	8	1
b-value:	50, 600, 800 (synthetic), 1000 (synthetic)	n/a
Scan time (min):	4:05	0:15 (sec.)

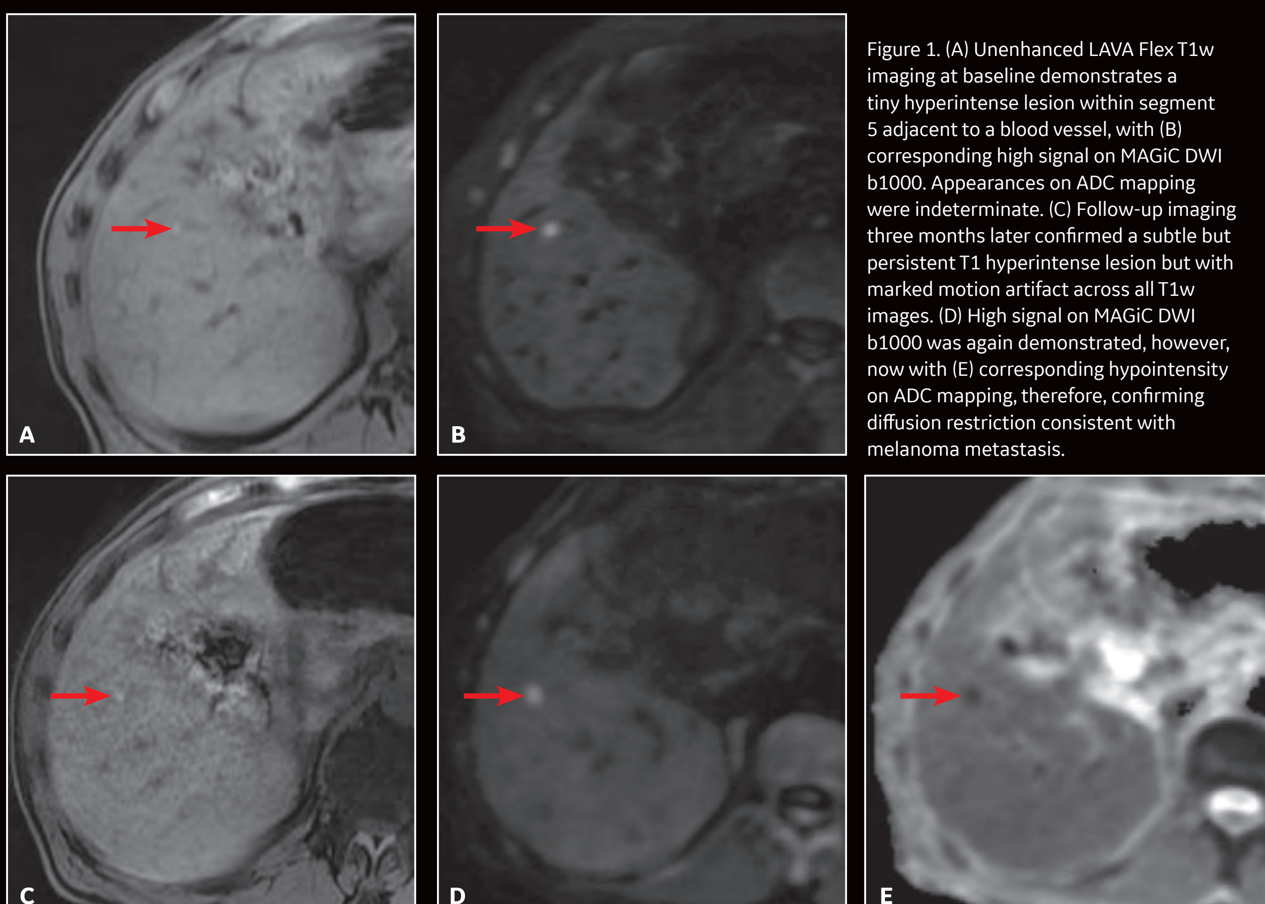

Figure 1. (A) Unenhanced LAVA Flex T1w imaging at baseline demonstrates a tiny hyperintense lesion within segment 5 adjacent to a blood vessel, with (B) corresponding high signal on MAGiC DWI b1000. Appearances on ADC mapping were indeterminate. (C) Follow-up imaging three months later confirmed a subtle but persistent T1 hyperintense lesion but with marked motion artifact across all T1w images. (D) High signal on MAGiC DWI b1000 was again demonstrated, however, now with (E) corresponding hypointensity on ADC mapping, therefore, confirming diffusion restriction consistent with melanoma metastasis.

MR findings

Unenhanced LAVA Flex T1-weighted imaging demonstrated a tiny hyperintense lesion within segment 5, of high signal on DWI but indeterminate Apparent Diffusion Coefficient (ADC) findings due to image artifact (Figure 1). Due to its small size and indeterminate nature, early interval imaging was advised, although initial findings were concerning, given the known innate T1 hyperintensity of melanoma metastases.

At follow-up, the patient's inability to breath-hold for some sequences resulted in suboptimal T1-weighted image quality but confirmed a persistent tiny hyperintense lesion, now with unequivocal restricted diffusion consistent with melanoma metastasis. In addition, a small hyperintense focus was visible within the right lung base, which in retrospect was present three months prior, although less conspicuous (Figure 2). On repeat review of the previous CT imaging performed at the same time as the original MR study, a tiny nodule was visible at this location, raising concern for pulmonary metastasis. Restaging CT imaging of the chest was advised, which confirmed an enlarging lung nodule consistent with metastatic disease. Patient management subsequently changed significantly to immunotherapy with avoidance of unnecessary surgery or locoregional therapy.

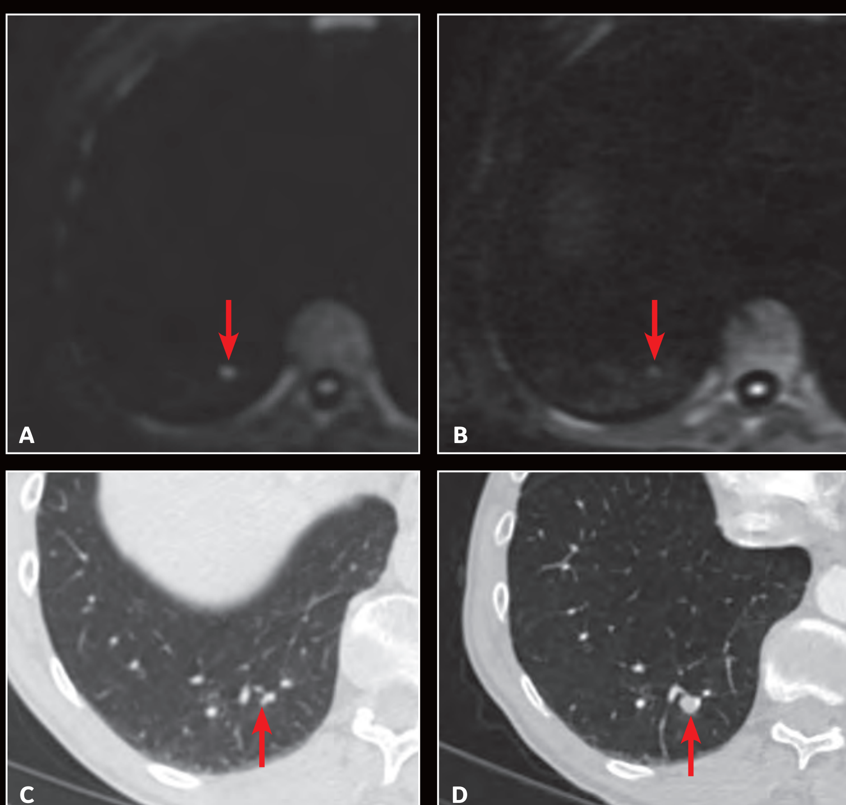

Figure 2. (A) Small nodule of diffusion restriction within the right lung base, MAGiC DWI b1000 image. (B) On reinspection of original baseline imaging from three months prior, a less conspicuous focus of diffusion restriction was present at the same location, possibly corresponding with (C) a 2 mm nodule seen only in retrospect at contemporaneous baseline CT. Given its location adjacent to a blood vessel, this would be almost impossible to identify in the absence of a DWI correlate. (D) A repeat CT staging study was therefore performed, which confirmed the presence of an enlarging pulmonary metastasis, equivalent to the nodule seen in (A).

Case 2

Patient history

A 57-year-old man with primary sclerosing cholangitis (PSC) resulting in cirrhosis, listed for transplantation and under surveillance due to elevated risk of cholangiocarcinoma and with deteriorating liver function tests.

Technique

Standard liver MR protocol including navigator-echo triggered high-resolution magnetic resonance cholangiopancreatography (MRCP), Axial T2-weighted PROPELLER image acquisition and navigator-echo triggered DWI (using b-values of 50 and 600) with MAGiC DWI-generated b-values of 800 and b1000 images.

MR findings

T2-weighted PROPELLER images demonstrated a typical dysmorphic liver with left lobe atrophy consistent with advanced PSC, widespread areas of geographic hyperintensity and subtle diffusion restriction consistent with fibrosis (Figure 3). Increasing extrahepatic duct dilatation was seen with an irregular stricture of the inferior common bile duct. High b-value (1000) MAGiC DWI clearly showed a ring of restricted diffusion at the level of the stricture, which could be matched to a subtle T2 hyperintense lesion aided by the use of image fusion (Figure 4). Endoscopic ultrasound evaluation confirmed the presence of a mural lesion with a luminal soft tissue component (Figure 5); biopsy confirmed cholangiocarcinoma. The patient was therefore removed from listing for transplantation.

Discussion

In both cases the high quality resolution and motion resistance of navigator-triggered DWI, in conjunction with utilization of high b-value synthetic images derived using MAGiC DWI, led to the identification of lesions that dramatically changed patient management. Previously, DWI has been partly hampered by issues relating to movement, susceptibility artifact and poor resolution; cases such as these clearly demonstrate that time invested in image acquisition during certain critical sequences is well-spent, while utilization of MAGiC DWI enabled time-savings from avoiding the acquisition of additional b-value images. An additional benefit of MAGiC DWI is the ability to calculate high b-value synthetic images without the lengthened TE that an acquisition would require, thereby improving image resolution and SNR as shown in the cases described.[4]

Discovery™ MR450

PARAMETERS	*Axial DWI*	*3D MRCP*	*Axial T2-weighted PROPELLER with Auto Navigator*
TR (ms):	8000	3750	1500
TE (ms):	51	665.4	75.2
FOV (cm):	36 x 29	38 x 28	36 x 36
Slice thickness (mm):	6	1.6	6.5
Frequency:	80	256	288
Phase:	128	224	288
NEX:	3	1	2
b-value:	50, 600, 800 (synthetic), 1000 (synthetic)	n/a	n/a
Scan time (min):	4:35	5:10	4:41
Options/other:		Navigator ASSET	

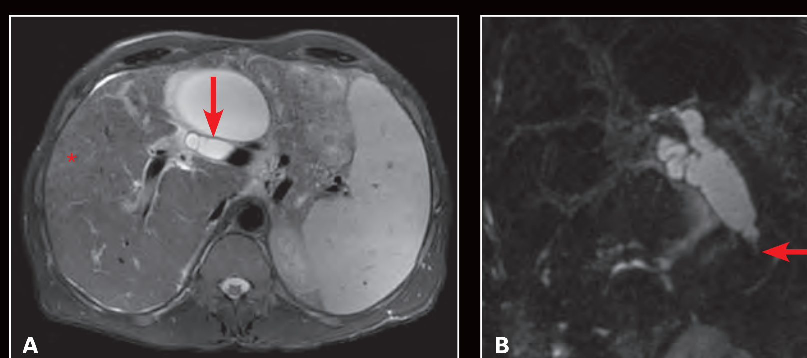

Figure 3. (A) Axial T2w PROPELLER image. Dysmorphic liver typical of advanced PSC with increasing dilatation of the common bile duct (arrow). Note the extensive T2 signal change within the background liver parenchyma consistent with fibrosis (asterisk). (B) Coronal MRCP maximum intensity projection (MIP) image demonstrating a shouldered, irregular stricture within the inferior duct.

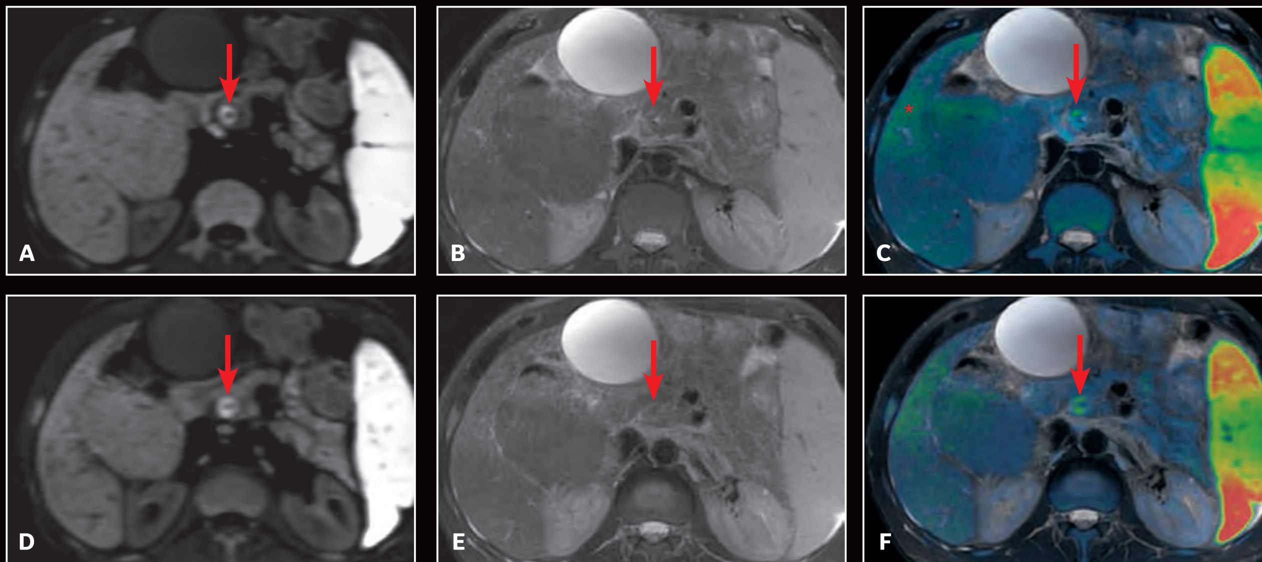

Figure 4. (A, D) MAGiC DWI b1000 images demonstrating a ring of restricted diffusion within the inferior common bile duct immediately upstream of the stricture shown in Figure 3B. (B, E) Axial T2w PROPELLER images fused with (C, F) false color DWI images demonstrate correlation with subtle irregular mural thickening and T2 hyperintensity at the level of the stricture (arrows). (C) Subtle diffusion restriction was also present within the regions of fibrosis (asterisk).

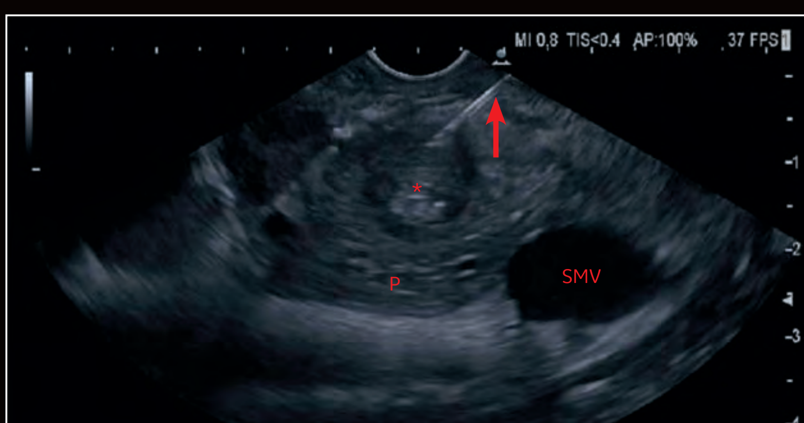

Figure 5. Axial endoscopic ultrasound image at/immediately below the abnormal mural thickening seen in Figure 4. (P) = pancreas, (SMV) = superior mesenteric vein. A core biopsy needle (arrow) can be seen entering luminal soft tissue (asterisk).

Image courtesy of Dr. N. Carroll, Consultant Radiologist, Cambridge University Hospitals.

Being able to confidently identify lesions only millimeters in size, including within the lung bases where technical issues such as motion and susceptibility artifact are normally significant factors of image degradation, leads to significantly improved diagnostic confidence. While breath-hold DWI has its place in certain patient groups with a low pre-test probability of disease, we now routinely employ navigator-triggered DWI and T2-weighted PROPELLER imaging to optimize image quality in challenging patient groups. S

Acknowledgements

Martin Graves, PhD, Consultant Clinical Scientist and Head of MR Physics, Cambridge University Hospitals; Simon Dezonie, Zone Clinical Leader, UK, GE Healthcare.

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2. Kircher, MF et al. Comparison of Breath-hold versus Free-breathing versus Respiratory Triggered and Navigator Triggered Diffusion Weighted Imaging of the Liver. Proc. Intl. Soc. Mag. Reson. Med. 19 (2011).p840.
3. Taouli B, Sandberg A, Stemmer A, et al. Diffusion-weighted imaging of the liver: comparison of navigator triggered and breathhold acquisitions. J Magn Reson Imaging. 2009 Sep;30(3):561-8.
4. Higaki T, Nakamura Y, Tatsugami F, et al. Introduction to the Technical Aspects of Computed Diffusion-weighted Imaging for Radiologists. Radiographics. 2018 Jul-Aug;38(4):1131-1144.

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3D MRCP with HyperSense: an evaluation of respiratory-triggered and breath-hold sequences

By Marc Zins, MD, Head of the Radiology Department, Saint-Joseph Hospital

Discovery™ MR750

PARAMETERS			
	3D Coronal MRCP RT	*3D Coronal MRCP RT HS*	*3D Coronal MRCP BH HS*
TR (ms):	6000	3333	1878
TE (ms):	888	882	1055
FOV (cm):	34 x 27	34 x 27	36 x 28
Slice thickness (mm):	1	1	2.8
Frequency:	416	416	384
Phase:	352	352	300
HyperSense factor:	–	1.6	2.2
NEX:	0.5	0.5	0.5
Scan time (min):	6:32	2:19	0:24 (sec.)
Options:	Zip2, FatSat, RT, Sat A/P, 50 kHz	Zip2, FatSat, RT, 50 kHz	Zip2, FatSat, 62.5 kHz

Magnetic resonance cholangiopancreatography (MRCP) is a highly accurate, non-invasive diagnostic test used to assess the hepatobiliary and pancreatic systems. A challenge is that patient compliance is required for respiratory-triggered and breath-hold sequences to achieve diagnostic-quality images.

In October 2016, our institution implemented SIGNA™Works, GE Healthcare's productivity platform of pulse sequences across core imaging techniques. SIGNA™Works includes HyperSense, a compressed sensing acceleration technique based on sparse data sampling and iterative reconstruction that enables faster scan times or higher resolution.

To evaluate the impact of HyperSense in MRCP exams, we performed a series of comparisons using our existing protocol, a conventional respiratory-triggered Coronal 3D MRCP, a Coronal 3D MRCP respiratory-triggered with HyperSense and a Coronal 3D MRCP breath-hold with HyperSense.

Technique

Each exam was performed on the Discovery™ MR750 3.0T system with a 32-channel torso coil. The protocol included patient fasting of at least four hours, which reduced the amount of fluid in the stomach and digestive tract, distended the gallbladder and limited duodenal peristalsis. There was no prior administration of anti-peristalsis. The ingestion of pineapple juice just before the examination helped to act as a negative contrast agent, due to the paramagnetic properties of the manganese contained in the juice, thus limiting signal interference related to the digestive tract fluid onto the resultant images.

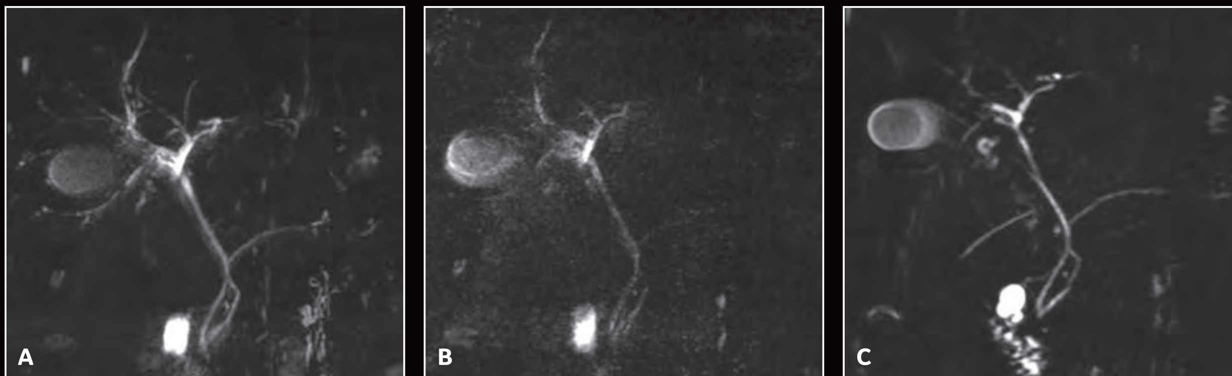


Figure 1. A 57-year-old female with unique IPMN of 12 mm situated in the head of the pancreas. (A) Conventional MRCP with respiratory-triggered sequence was acquired in 5:27 min.; (B) MRCP with respiratory-triggered and HyperSense acquired in 1:59 min.; and (C) MRCP breath-hold with HyperSense. The breath-hold sequence provides the same diagnostic information as the conventional sequence but in a far shorter scan time of 24 sec. and with fewer motion artifacts.

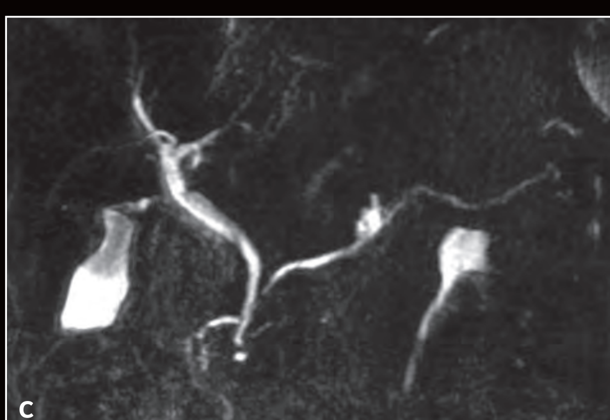


Figure 2. A 77-year-old female with a cystic lesion located in the pancreas body, in favor of an IPMN. (A) Conventional MRCP with respiratory-triggered sequence was acquired in 3:39 min.; (B) MRCP with respiratory-triggered and HyperSense was acquired in 2:19 min.; and (C) MRCP breath-hold with HyperSense was acquired in 21 sec. In this case, the patient could not hold their breath perfectly. The respiratory-triggered sequence with HyperSense was able to provide the same diagnostic information as the conventional sequence with a reduced scan time.

MR findings

First, we compared the respiratory-triggered conventional 3D MRCP against the respiratory-triggered HyperSense 3D MRCP sequence using a factor of 1.6. In almost all cases, we achieved similar image quality, however, with HyperSense we were able to reduce the sequence scan time by at least 34 percent. We were also able to reduce artifacts in the respiratory-triggered sequence with the addition of HyperSense due to the shortened exam time.

Next, we evaluated the respiratory-triggered HyperSense sequence against the HyperSense breath-hold sequence using the same factor of 2.2. While the spatial resolution was not the same between these two sequences, we found that the 3D MRCP breath-hold HyperSense sequence could often

Figure 3. A 53-year-old female with a 3 cm mass located in the pancreas head, which led to main and secondary pancreatic ducts dilation as well as intra- and extra-hepatic biliary ducts dilation. (A) Conventional MRCP with respiratory-triggered sequence was acquired in 6:32 min.; (B) MRCP with respiratory-triggered and HyperSense was acquired in 4:08 min.; and (C) MRCP breath-hold with HyperSense was acquired in 21 sec. All sequences provided the same diagnostic information.

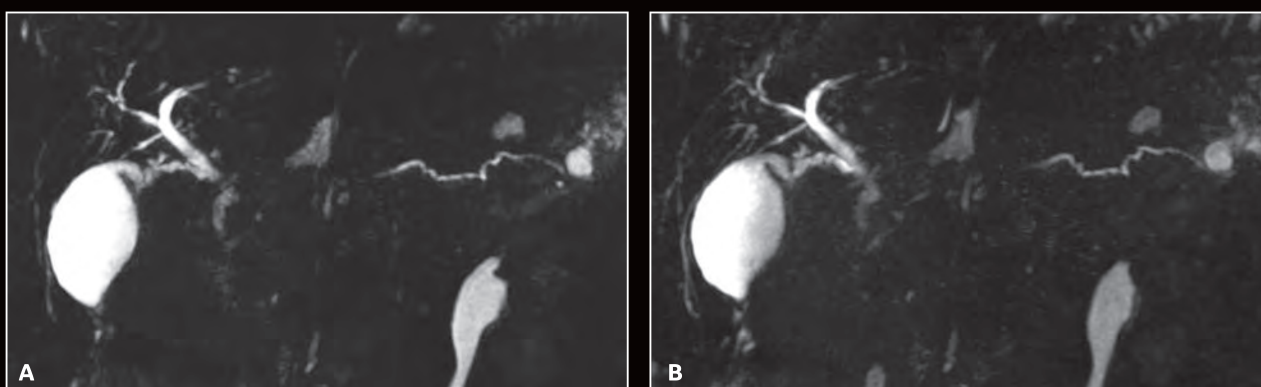
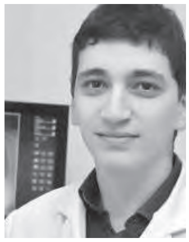


Figure 4. A 62-year-old female with a 8 mm cystic mass located in the pancreas tail. (A) Conventional MRCP with respiratory-triggered sequence was acquired in 3:46 min.; (B) MRCP with respiratory-triggered and HyperSense was acquired in 2:29 min.; and (C) MRCP breath-hold with HyperSense was acquired in 23 sec. The breath-hold sequence provides the same diagnostic information as the conventional sequence but in a far shorter scan time of 23 sec. The main pancreatic duct is better depicted on the breath-hold sequence, due to motion artifacts present on both triggered sequences.

provide the information needed for a confident diagnosis. Plus, by using HyperSense, the breath-hold sequence could be reduced to 24 seconds or less without respiratory-induced artifacts.

As a result of our evaluation, the Coronal 3D MRCP respiratory-triggered with HyperSense factor of 1.6 sequence has now replaced the conventional respiratory-triggered Coronal 3D MRCP sequence in our facility. Additionally, in patients who cannot tolerate the high-resolution, respiratory-triggered 3D MRCP with HyperSense scan, the Coronal 3D MRCP breath-hold HyperSense factor of 2.2 sequence is an excellent option that can result in a successful examination.



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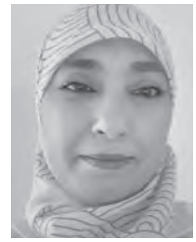

Orkia Ferdagha
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Detecting ischemia-induced cardiac fibrosis with phase sensitive MDE

By Abdelhamid Derriche, MD, site radiologist, and Orkia Ferdagha, MR technologist, PRIISM, EHP Kara

In cardiac patients, particularly those who have a history of ischemia, determining myocardial viability is critical for planning the patient care pathway as it allows us to identify patients who would not benefit from angioplasty. Myocardial delayed enhancement (MDE) sequences are typically employed for these studies.

A strong saturation of healthy myocardium signal on MDE sequences allows for a better delineation and assessment of ischemic induced cardiac fibrosis. However, the most optimal inversion time value (TI) is needed for acquiring a reliable and clinically useful MDE study. Cine IR allows us to obtain this value even though the TI time continually changes as the contrast washes out.‡

The introduction of a phase sensitive MDE (PS MDE) sequence now allows for better suppression of healthy myocardium signal even with non-optimal TI values. Additionally, we can avoid rescanning patients in cases of poorly suppressed healthy myocardium signal due to incorrect TI value selection by only evaluating the PS MDE sequence (see Figure 1).

SIGNA™ Explorer

PARAMETERS

	FIESTA Gated Cine SA	*FIESTA Gated Cine LA*	*FIESTA Gated Cine 4 chambers*	*FIESTA Gated Cine LVOT*	*Tagging SA*	*Perfusion, multi planes in SA + 4 chambers*	*2D MDE SA*	*2D MDE 4 chambers*	*2D MDE LA*	*PS MDE SA*
TR (ms):	4.3	4.3	4.1	4.3	5	3.3	4.9	4.8	4.7	7.6
TE (ms):	1.9	1.9	1.8	1.9	2.3	1.6	1.4	1.4	1.3	3.5
FOV (cm):	38	38	38	38	40 x 28	38 x 34.2	40 x 36	40 x 36	40 x 36	38 x 34.2
Slice thickness (mm):	8	8	8	8	8	10	9	9	9	9
Frequency:	224	224	224	224	256	128	224	224	224	200
Phase:	224	224	224	224	192	96	160	160	160	192
NEX:	1	1	1	1	1	0.75	3	3	3	1
Scan time (min):	1:15	1:17	1:09	0:19 (sec.)	1:49	1:04	2:06	1:59	2:11	2:00
Options / other:							After 8 min. of contrast bolus			After 25 min. of contrast bolus

‡Drug products should be used in accordance with their approved labeling. Gadolinium-based contrast agents have not been approved for cardiac use in all regions.

Figure 1. Comparison of 2D MDE and PS MDE. PS MDE provides better visualization of the fibrosis and better suppression of healthy myocardium signal even with non-optimal TI values. (A) 2D MDE SA, 2:06 min; (B) magnitude PS MDE; (C) phase PS MDE SA. Yellow arrows indicate ischemia induced fibrosis; (B-C) red arrows depict a healthy myocardium signal not suppressed on magnitude PS MDE with sub-optimal TI value; using the phase sensitive image from the same acquisition helped to fix this issue.

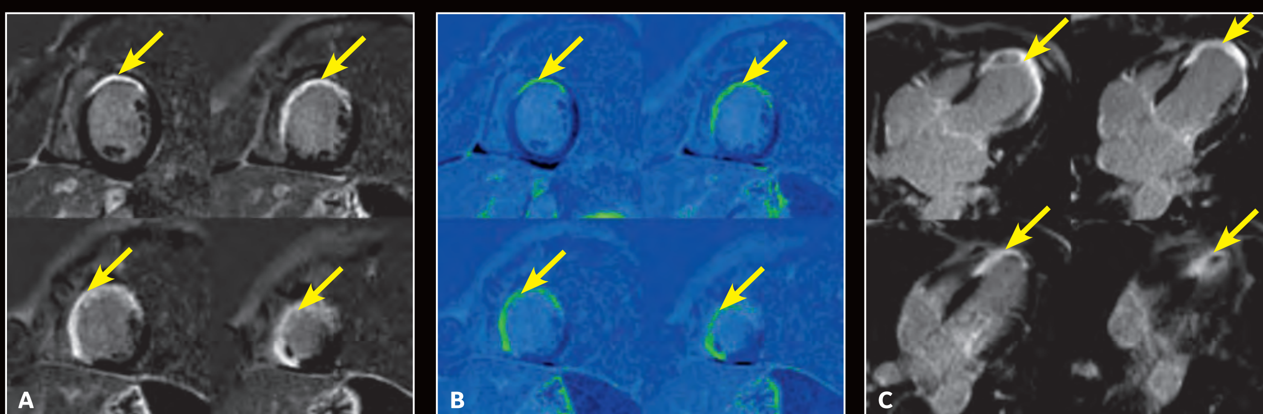

Figure 2. Myocardial viability study. (A, B with color map) 2D PS MDE SA, 1:59 min.; and (C) 2D MDE 4 chambers, 2 min. Yellow arrows indicate ischemia-induced fibrosis.

Patient history

A 60-year-old male with a history of cardiac ischemia referred for a myocardial viability MR exam including function, perfusion and the qualitative analysis of the myocardial viability. The patient has ischemia-induced fibrosis on diseased heart tissues.

MR findings

The left ventricular (LV) function study provides an estimated fractional ejection of 24% and depicts a diffuse akinetic apical contraction with midventricular hypokinesia with anteroseptal predominance.

Perfusion study shows an anomaly with delayed and reduced contrast enhancement with predominance on the subendocardial antero-septo-lateral midventricular region.

MDE demonstrates a systematic myocardial fibrosis belonging to the left anterior descending (LAD) coronary territory (see Figure 2). With contrast uptake we found:

- Transmural on apical anteroseptal;
- Transmural on midventricular septal;
- Inferior to 50% of myocardial thickness on subendocardial anterior midventricular region;
- Sub-endocardial no-reflow phenomenon on the infero-septal region of the apex (also observed on perfusion sequence);
- No regional myocardial parietal thinning of less than 6 mm.

Patient underwent angioplasty and recovered some cardiac function.

Discussion

Using PS MDE, it was possible to assess myocardial necrosis with systematized transmural fibrosis on the LAD coronary territory in the apical anteroseptal region and midventricular septal region as non-viability criteria. Additionally, we determined myocardial ischemia with subendocardial fibrosis inferior to 50% of parietal thickness of the anterior segment of the midventricular region with viability criteria as well as hypokinesia of apical and midventricular regions with diminution of LV fractional ejection.

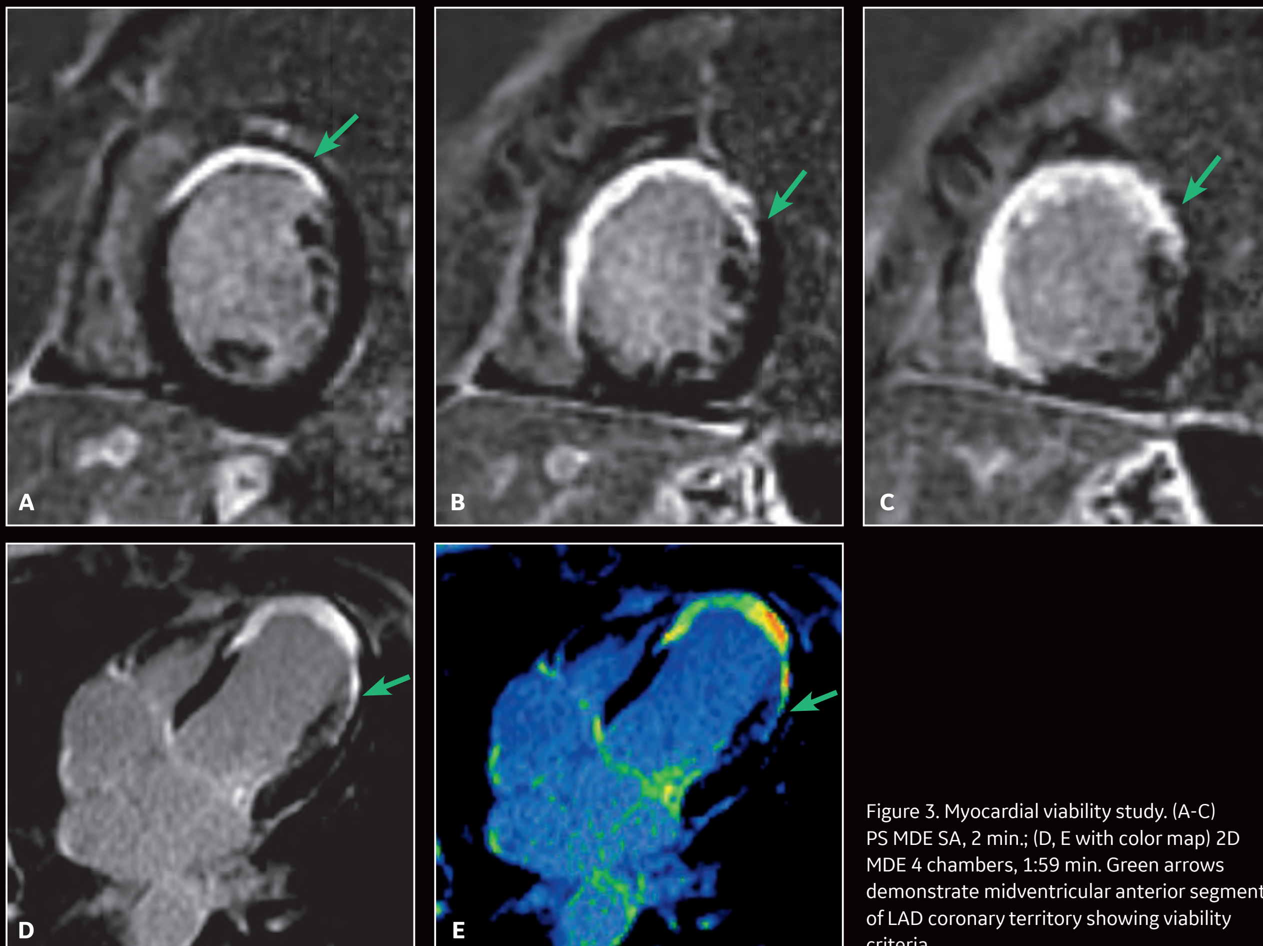

Figure 3. Myocardial viability study. (A-C) PS MDE SA, 2 min.; (D, E with color map) 2D MDE 4 chambers, 1:59 min. Green arrows demonstrate midventricular anterior segment of LAD coronary territory showing viability criteria.

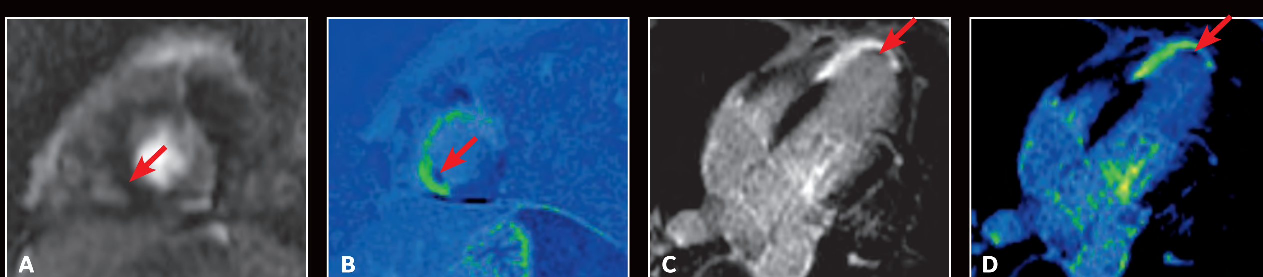

Figure 4. (A) Perfusion FGRE TC SA, 1:04 min.; (B) PS MDE SA with color map, 2 min.; and (C, D with color map) 2D MDE 4 chambers, 1:59 min. Red arrows show the sub-endocardial no-reflow phenomenon on the inferoseptal region of the apex.

PS MDE provides very good contrast and good delineation of fibrosis, especially in cases where determining the optimal TI value is complicated. We now have an alternative with PS MDE that appears to be as efficient as the traditional MDE sequence.

Cardiac MR (CMR) brings a new level of detail and depth to our diagnosis and management of coronary disease. In particular, it supports management of hypertrophic cardiomyopathy patients and post-operative follow-up in Tetralogy of Fallot cases. With CMR and an advanced 1.5T MR system such as SIGNA™ Explorer, we have higher clinical confidence due to excellent imaging capabilities that assists us in myocardium viability studies as well as diagnosing difficult-to-detect conditions, such as myocarditis and arrhythmogenic right ventricular dysplasia. CMR on the SIGNA™ Explorer adds real value to patient care.

SIGNA™ Works: tuned for productivity and efficient workflows

By Steve Lawson, RT(R)(MR), Global MR Clinical Marketing Manager, and Heide Harris, RT(R)(MR), Global Product Marketing Director, MR Applications and Visualization, GE Healthcare

Patient motion and magnetic field distortions, such as susceptibility effects, are common issues impacting image quality and efficiency (e.g., scan times) in MR imaging. GE Healthcare provides an array of sequences and solutions designed to take MR to the next level of productivity. Even better, SIGNA™ Works is value-added technology that is upgradable and customizable to meet the specific needs of different practices.

MR is one of the most complex imaging studies a radiologic technologist acquires. From patient positioning with phased array coils to determining the precise prescription for the imaging study, there are many variables that can impact not only the quality of the study but the efficiency and productivity of technologists and the MR system.

One of the most common issues impacting productivity is patient motion. In a published study, a retrospective review of one calendar week of MR exams found significant motion artifacts on sequences in 19.8 percent of the total completed MR exams.[1] The authors estimated the potential cost to the hospital to be $592 per hour in lost revenue and a median revenue foregone of approximately $115,000 per scanner, per year.[1]

Respiratory motion is a leading cause of artifacts degrading imaging quality. Many elderly or acutely ill patients cannot hold their breath for the duration of the acquisition. Other causes of motion artifacts include cardiac movement and CSF pulsation/blood flow.

One approach to reducing motion artifacts is to increase scanning speed to decrease overall MR exam times. This can be accomplished with parallel imaging and compressed sensing techniques, which can also have the added impact of reducing total scan time and potentially enabling additional scheduling slots. For respiratory motion, there are free-breathing techniques for patients that cannot hold their breath, including respiratory-gating, respiratory-triggered and Auto Navigator techniques.

Magnetic field distortions can also be created by susceptibility effects that lead to signal loss, primarily in T2-weighted relaxation and spatial mismapping. The result is a signal void in the MR image or areas that have a very bright signal due to a "pile up," where the signal is "assigned" to the wrong area(s). Susceptibility artifacts may be common in patients with metal implants, screws or clips (e.g., aneurysm clip), as well as in diffusion-weighted (DWI) sequences. MR exams suffering from susceptibility effects can decrease system and technologist productivity when the region of interest in the MR image is distorted due to these artifacts.

Here's a look at the available sequences and techniques that GE Healthcare offers in the SIGNA™ Works productivity platform to address these issues.

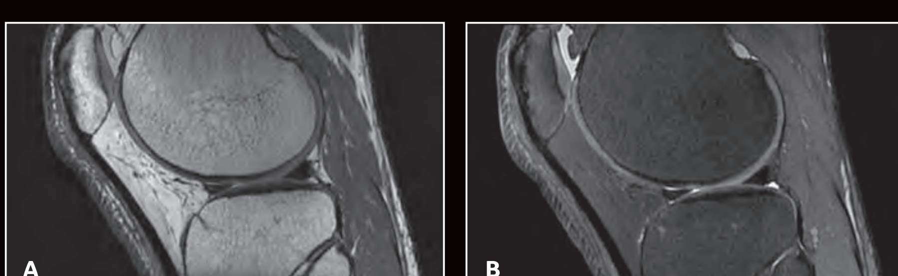

Figure 1. Cube PD with HyperSense and ARC enables a 10-min isotropic knee exam. (A) Cube PD with HyperSense and ARC; (B) Cube PD FatSat with HyperSense and ARC. Both sequences acquired in 5 min TE/TR = min/1000 ms, FOV 16 cm, ARC 2 x 2, HyperSense factor of 1.2, 0.5 mm isotropic.

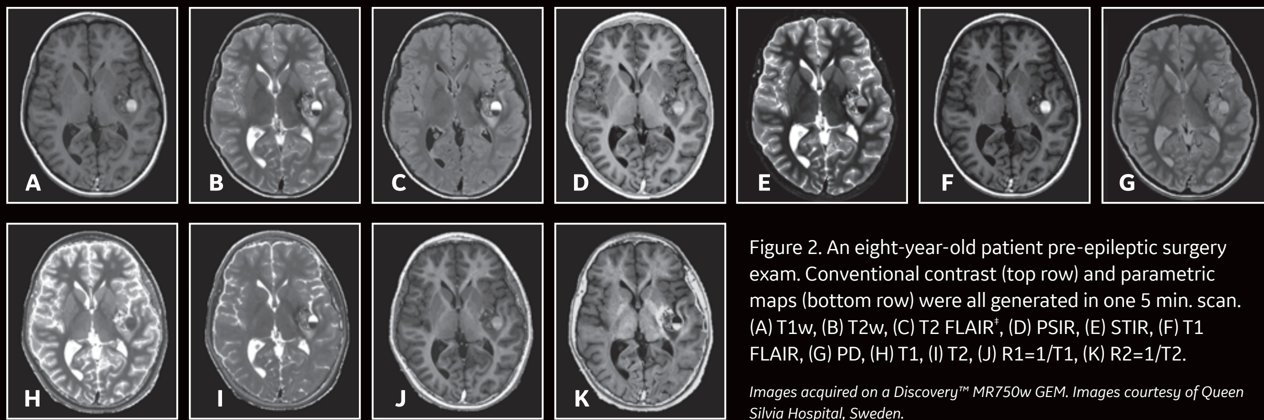

Figure 2. An eight-year-old patient pre-epileptic surgery exam. Conventional contrast (top row) and parametric maps (bottom row) were all generated in one 5 min. scan. (A) T1w, (B) T2w, (C) T2 FLAIR‡, (D) PSIR, (E) STIR, (F) T1 FLAIR, (G) PD, (H) T1, (I) T2, (J) R1=1/T1, (K) R2=1/T2.

Images acquired on a Discovery™ MR750w GEM. Images courtesy of Queen Silvia Hospital, Sweden.

Acceleration techniques

HyperWorks is a collection of advanced acceleration techniques that deliver fast scanning—up to 8 times faster—with excellent image quality. Designed to speed up scanning to reduce the potential for motion artifacts and, therefore, repeat exams, HyperWorks includes HyperSense, HyperBand and HyperCube.

- **HyperSense** is a compressed sensing acceleration technique based on sparse data sampling and iterative reconstruction, enabling faster imaging without the penalties commonly found with conventional parallel imaging. It uses a mathematical approach to identify and calculate data into an image versus scanning to collect all the data needed for that image. It can be used for 88 percent of all clinical procedures and is compatible with Cube and TOF sequences.
- **HyperBand**, compatible with DWI and diffusion tensor imaging (DTI) and ARC, speeds up scan time by exciting and acquiring multiple slices simultaneously to shorten acquisition time. HyperBand also allows the ability to acquire thinner slices in the same scan time for DWI or acquire more diffusion tensor directions on DTI.
- **HyperCube** accelerates small field-of-view (FOV) 3D volumetric imaging for more detail in less time without having to scan the entire FOV or use no-phase wrap. It lowers scan time without SNR loss, eliminates time-consuming parameters and enables better image quality. For large FOV robust fat suppression, HyperCube can be combined with Flex.

ARC is auto-calibrating, which means that it requires no coil sensitivity map and is therefore less sensitive to motion artifacts that would occur between the calibration and accelerated scan. It can be used with tight FOVs that are smaller than the anatomy being imaged and thus allow high-resolution imaging.

Synthetic MR

MAGiC is a multi-delay, multi-echo FSE sequence that generates images of any TR, TE and TI after a single scan has been acquired, even after the patient is gone. It automatically outputs eight contrasts—T1, T2, PD, T1 FLAIR, T2 FLAIR‡, STIR, DIR and PSIR—in approximately 5 minutes of scan time. In addition, MAGiC provides quantitative parametric maps, including T1, T2, R1, R2 and PD. MAGiC can provide more diagnostic information without adding scan time even after the patient has left.

MAGiC DWI is a synthetic DWI sequence that calculates multiple b-values from a single DWI scan. In DWI, increasing the b-value decreases SNR and increasing the number of b-values increases scan time. MAGiC DWI address both of these issues by synthetically calculating and providing multiple and higher b-values. In fact, it provides higher b-values than what can be acquired and improves image sharpness and SNR with shorter TEs. It is compatible with all diffusion directions and coils.

Volumetric MR

Cube, a volumetric FSE-based sequence, allows an image captured in one plane to be reformatted to any other scan plane, potentially eliminating the need for additional multi-planar 2D FSE acquisitions. Compatible with both free-breathing and respiratory-triggered sequences to reduce motion artifacts, Cube also decreases flow artifacts in the spine, ortho and brain applications. Since Cube modulates the RF pulse, there is reduced blurring, commonly associated with long Echo Train Length sequences. It can also be utilized with ARC and/or HyperSense to further reduce scan time, making 3D acquisitions consistently attainable.

Flex for Cube and FSE Flex use a 2-point Dixon technique for homogeneous FatSat with water, fat, in-phase and out-of-phase images in a single scan. With Cube Flex, the technologist can scan once and then reformat to any plane with high sub-millimeter resolution. FSE Flex acquires multiple contrasts in a single scan, reducing the need for multiple acquisitions, which is particularly useful for post-contrast spine or MSK imaging.

‡It is recommended to acquire conventional T2 FLAIR images in addition to MAGiC.

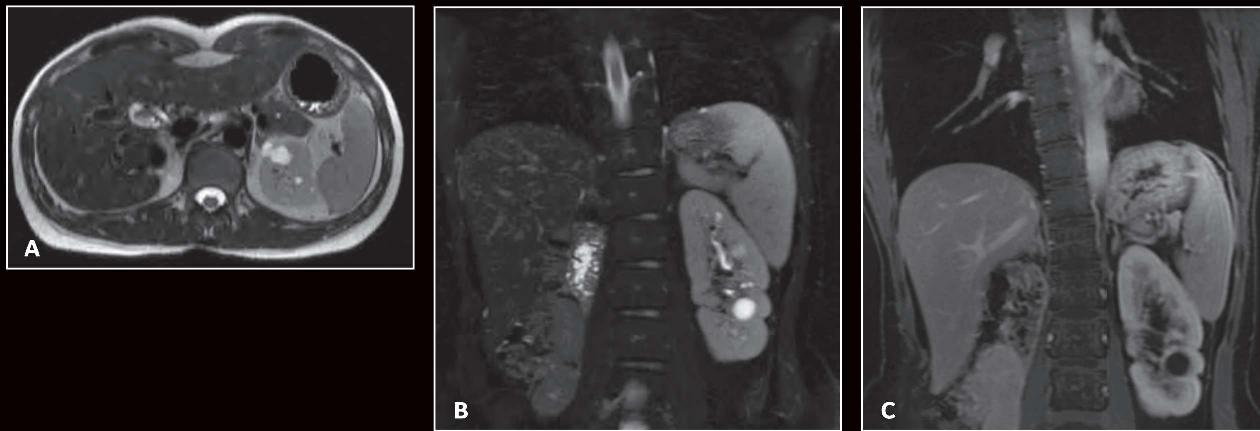

Figure 3. DISCO with Auto Navigator enables a free-breathing dynamic DCE liver exam with high resolution. (A) Axial T2 SSFSE 352 x 224, 4 mm slice, scan time of 40 sec.; (B) Coronal T2 SSFSE, 320 x 224, 4 mm slice, scan time of 33 sec.; and (C) Coronal Turbo LAVA, 320 x 192, 3 mm slice, scan time of 19 sec.

Images courtesy of Seirei Hamamatsu Hospital, Japan.

ViosWorks delivers a comprehensive cardiac anatomy, function and flow in a free-breathing, eight-minute scan. It provides visualization and quantification of 4D flow, tools to assess and quantify complex hemodynamics in cardiovascular disease, and increases productivity and patient comfort by acquiring one 3D volume over the chest. When used with HyperKat, ViosWorks reduces the number of slices needed. Cloud-based post-processing powered by Arterys™ also allows image analysis from anywhere using an internet browser.

Motion

PROPELLER is a multi-shot approach that preserves tissue contrast regardless of weighting while also reducing motion artifacts and providing a more signal rich image. Rather than filling *k*-space line-by-line, PROPELLER fills it with an arrangement of "blades" that are rotated in *k*-space at incremental angles, resulting in an oversampling of the center of *k*-space for a more signal-rich image. It delivers motion-artifact-reduced diagnostic images that are not impacted by respiration and peristalsis, potentially decreases the number of repeat scans and enables sedation-free scanning.

More recently, **PROPELLER Multi-shot Blade (MB)** advancements combine multiple blades together to achieve shorter TEs and improved motion correction. It allows for true T1 and PD contrast imaging. Both PROPELLER and PROPELLER MB are compatible with Auto Navigator.

PROMO (PROspective MOtion correction) delivers prospective motion correction for 3D brain imaging when combined with Cube T2, Cube FLAIR and Cube DIR. Motion is measured in real time by acquiring three-plane spiral Auto Navigator with a motion tracking algorithm. A mask is applied to navigators to remove non-rigidly moving tissue from motion estimates. Six rigid motion parameters are produced in real time by the PROMO tracking algorithm to prospectively correct for a patient's motion during the scan.

Auto Navigator, a free-breathing approach, combats respiratory motion for body, cardiac and chest imaging with automatic tracker placement. It is compatible with all critical body imaging sequences, such as diffusion, PROPELLER, T2 MRCP and dynamic T1 imaging (LAVA, LAVA Flex and DISCO).

The navigator tracker is automatically placed over the right hemidiaphragm and synchronizes with the patient's breathing pattern to minimize respiratory ghosting artifacts. Real-time adjustment allows threshold levels and acceptance window to be adjusted during the acquisition, eliminating failures due to changes in the patient's respiratory pattern. Auto Navigator can gate or trigger the patient's respiratory cycle.

High susceptibility

MAVRIC SL is designed to greatly reduce artifacts caused by the presence of MR-Conditional metal implants, substantially reducing susceptibility artifacts and significantly improving visualization of bone and soft tissue. It provides the potential to visualize arthroscopic complications, fluid near an implant and adverse local tissue reaction. MAVRIC SL acquires several 3D FSE images at multiple spectral offsets that are combined into a single 3D composite data set to remove distortions commonly caused by MR-Conditional metal implants. It also has a T1-weighting capability for pre- and post-contrast enhancement.

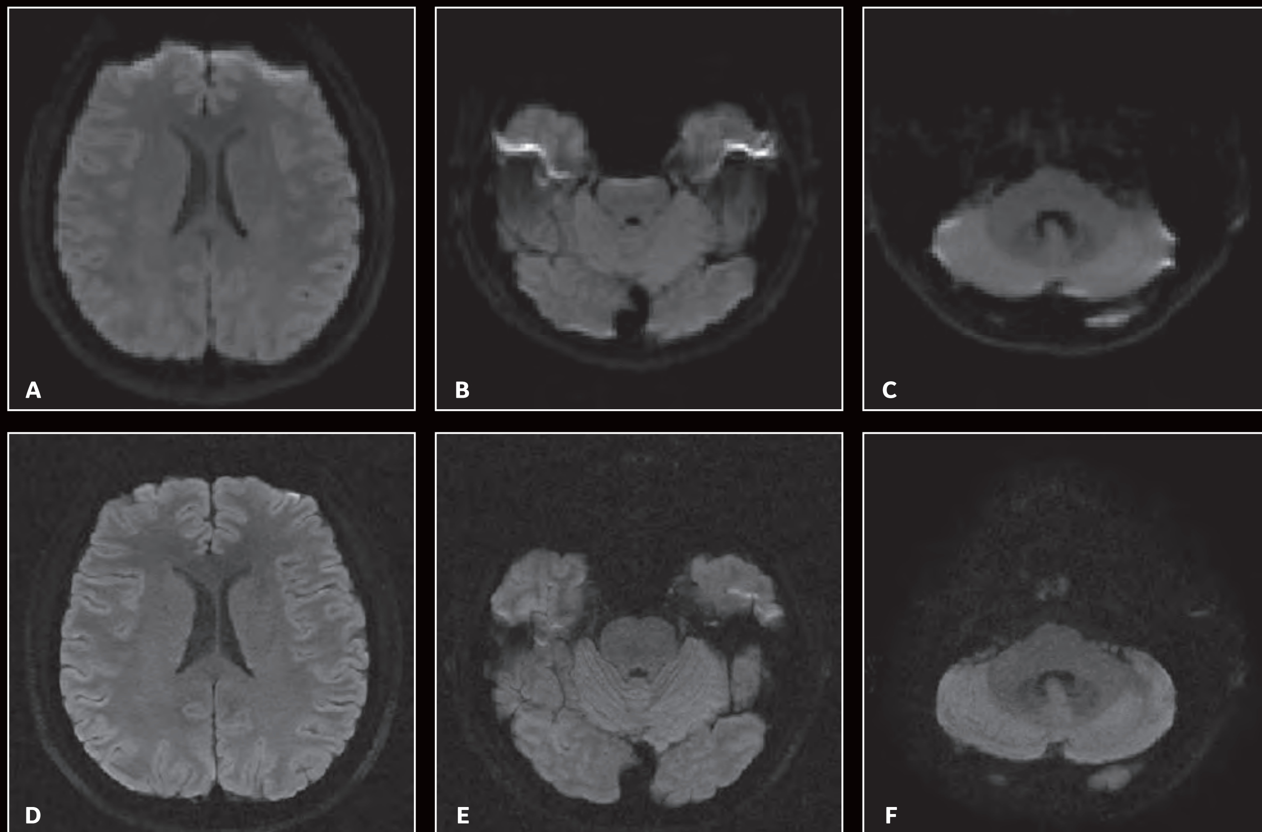

Figure 4. MUSE allows for advanced diffusion with reduced distortion and increased resolution. (A-C) SS diffusion, 2 x 2 x 3 mm. (D-F) 16-shot MUSE, 0.75 x 0.75 x 3 mm.

Images courtesy of Duke University, North Carolina, USA.

FOCUS DWI, an EPI diffusion technique, enables smaller FOV imaging of anatomy for constrained, undistorted single-shot diffusion imaging. This 2D spatially-selective RF excitation method for DW-EPI and DTI is designed to reduce FOV in-phase encode direction within the imaging plane to reduce geometric distortion and eliminate phase wrap artifacts. By using a small FOV, FOCUS DWI increases image sharpness and resolution, and delivers less blurring and distortion in high susceptibility areas. It is ideal for use in the spine, prostate, gynecologic, brain and pancreas imaging and can be used with 1.5T and 3.0T systems.

MUSE (MUltiplexed Sensitivity Encoding) reduces blurring and susceptibility induced distortions compared to conventional parallel imaging techniques while pushing the boundaries of spatial resolution for DWI/DTI imaging. Traditionally, higher resolution DWI/DTI imaging was challenged because of imaging artifacts. The longer readout length and echo spacing lead to blurring and susceptibility artifacts. MUSE improves DWI and DTI image quality by acquiring phase-segmented DW-EPI and allowing higher resolution diffusion imaging in large matrix sizes, up to 512 x 512. It provides submillimeter in-plane image resolution and can be combined with in- and through-plane image acceleration techniques for enhanced speed and coverage. MUSE is particularly beneficial in anatomical areas that are vulnerable to susceptibility artifacts, such as the brain and prostate.

PROGRES, which includes **Distortion Correction**, addresses distortion in diffusion scans that typically arise from B_0 inhomogeneity and the EPI readout but can also occur less frequently from motion and gradient-related imperfections such as eddy currents. This technique uses a "reverse polarity" acquisition and automated advanced processing to eliminate sources of distortion. It is most effective when SNR is high and provides the best high-resolution distortion reduction when combined with MUSE. S

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University of Sheffield
Sheffield, England

Hyperpolarized gas lung imaging

The POLARIS group at University of Sheffield, led by Jim Wild, PhD, Professor of Magnetic Resonance Physics and a NIHR Research Professor in Pulmonary Imaging, has been working on hyperpolarized gas lung MR imaging. Their research and technical developments have made a clinical impact on the National Health Service (NHS) practice in the diagnosis and management of patients with asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis, interstitial lung disease, lung cancer and pulmonary hypertension.

In 2016, the Medicines and Healthcare products Regulatory Agency (MHRA) in the United Kingdom approved the use of hyperpolarized gas lung MR imaging for clinical diagnostic referral at the University of Sheffield. Professor Wild now manufactures helium 3 (^{3}He) and xenon 129 (^{129}Xe) for diagnostic MRI for clinical imaging use. Through the NHS, patients are referred to the Royal Hallamshire Hospital, Sheffield Children's Hospital, and other NHS trusts throughout the UK for hyperpolarized gas and proton lung MR imaging. With MR, they can obtain more insight on a patient's lung function beyond ventilation.

"The technology allows us to image lung ventilation, gas exchange and microstructure," Professor Wild explains. "We can image the ventilated air spaces and obtain information on lung ventilation changes in obstructed airway diseases, like cystic fibrosis, asthma and COPD."

Also, because xenon is soluble, the gas dissolves in the alveoli in the lungs and goes into the capillaries. This allows measuring and quantifying interstitial changes in fibrotic lung disease and provides insight on ventilation perfusion (VQ) matching. Clinicians can also measure alveoli dimensions by measuring the diffusivity of the gas, which provides metrics on early emphysema changes in smokers and on lung development in infants.

Xenon is an MR-sensitive gas. To image the low concentrations of gas inhaled in the air in the lungs, the spin magnetization needs to be boosted by laser optical pumping. The Sheffield group has built a laser polarizer[1‡] that generates highly polarized ^{129}Xe on demand in order to allow high-throughput clinical lung imaging with modest inhaled doses of xenon (500 ml). Using conventional MR scanners (Optima™ MR450w) fitted with a broadband RF amplifier[‡], the MR is tuned to a frequency that can detect the hyperpolarized ^{129}Xe. Xenon has a resonant frequency of approximately 25 percent of proton MR; therefore, dedicated RF coils are required.[‡]

"Our research is geared to making this methodology work on clinically available MR systems," Professor Wild says. "It involves retuning the MR scanner to pick up xenon, designing additional coils to do lung and brain xenon imaging, developing methods to interpret the signals and deriving physiological biomarkers from this kind of imaging. We work closely with GE on the MR hardware and software development for this, particularly in the area of RF coil and pulse sequence developments."

The team has explored the use of parallel imaging methods for

‡ Technology in development that represents ongoing research and development efforts. These technologies are not products and may never become products. Not for sale. Not cleared or approved by the US FDA or any other global regulator for commercial availability.

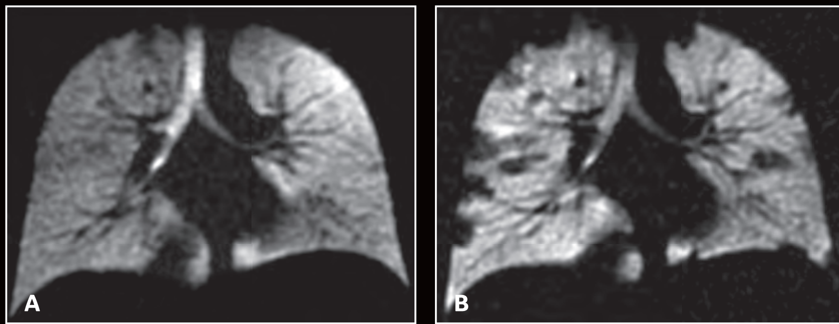

Figure 1. Pediatric patient with cystic fibrosis. (A) Baseline, ventilation defect percent (VDP) = 3.14%, CV_{mean} = 16.94%, forced expiratory volume in 1 sec. (FEV1) (z-score) = -0.51, LCI = 6.63. (B) Two-year follow-up, VDP = 20.70%, CV_{mean} = 20.15%, FEV1 (z-score) = -0.75, LCI = 8.68.

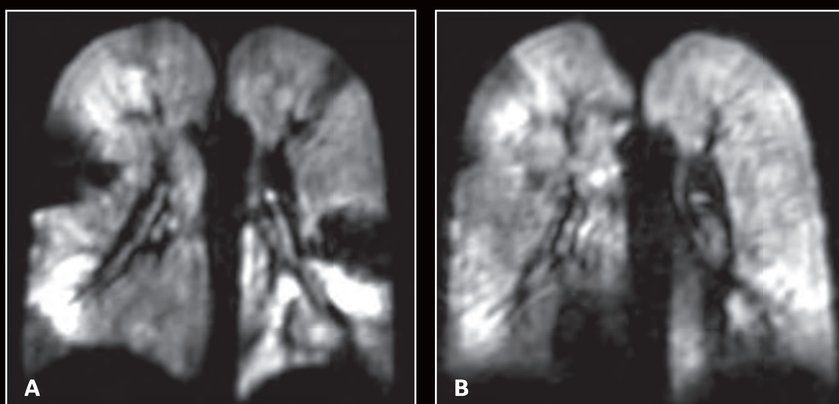

Figure 2. A 13-year-old cross country runner with decreasing race times with chronic cough and increased sputum production. FEV1 was normal. Patient underwent hyperpolarized ^{129}Xe MR imaging, was diagnosed with non-cystic fibrosis bronchiectasis and treated with IV antibiotics. (A) Baseline, (B) two-weeks after IV therapy.

hyperpolarized gas MR imaging with a homogeneous field. To accomplish this, they developed a flexible 32-channel receive array‡ to use with an asymmetric birdcage transmit coil‡, which enables high SNR in an accelerated acquisition. The asymmetric birdcage was shown to provide a homogeneous flip angle over the large FOV needed to image the entire lung, while the flexible receive array allowed it to be placed close to the patient's chest to enable high acceleration factors. The reduction in scan time provided by the use of parallel imaging allowed shorter patient breath-holds.[2]

In collaboration with GE Healthcare, Professor Wild and his team at Sheffield also developed a dedicated 1H receiver array‡ that could improve the SNR that captures both function and structure for use in same-breath acquisition with hyperpolarized gas ^{3}He or ^{129}Xe without having to move the patient or switch coils.[3]

"The ability to rapidly switch the scanner to image one nucleus and then the next to obtain functional and structural information together from the same coil is very interesting methodologically," he says. "In one project, we have worked closely with GE on ways for rapidly switching the scanner coils between different nuclear frequencies using micro-electro-mechanical switches."[4]

Since the xenon is inhaled, it also goes into the blood. With the long relaxation time of xenon, Professor Wild and his colleagues have imaged it in other organs.

"We've picked up dissolved xenon in the brain and kidneys, so we can monitor cerebral perfusion and kidney perfusion with this technique," he adds.[5,6]

Evidence-based studies

In a published clinical study of 19 pediatric patients with clinically stable mild cystic fibrosis, hyperpolarized gas ventilation MR was found to be the most sensitive method for detecting abnormalities. The technique also provides detailed regional information on physiological impairment and disease severity, as well as longitudinal changes in lung function.[7]

"This study demonstrated the ability to follow a given patient and assess their lung function over time, something that cannot be obtained by pulmonary function tests," explains Professor Wild.

Another study examined the use of hyperpolarized ^{129}Xe MR imaging in 18 patients with idiopathic pulmonary fibrosis (IPF). Professor Wild and co-authors concluded that this technique may be sensitive to short-term changes in interstitial gas diffusion in patients with IPF. This is important because prognosticating IPF remains challenging due to the absence of sensitive biomarkers. Existing pulmonary function tests, such as forced vital capacity (FVC) and diffusing capacity of the lungs for

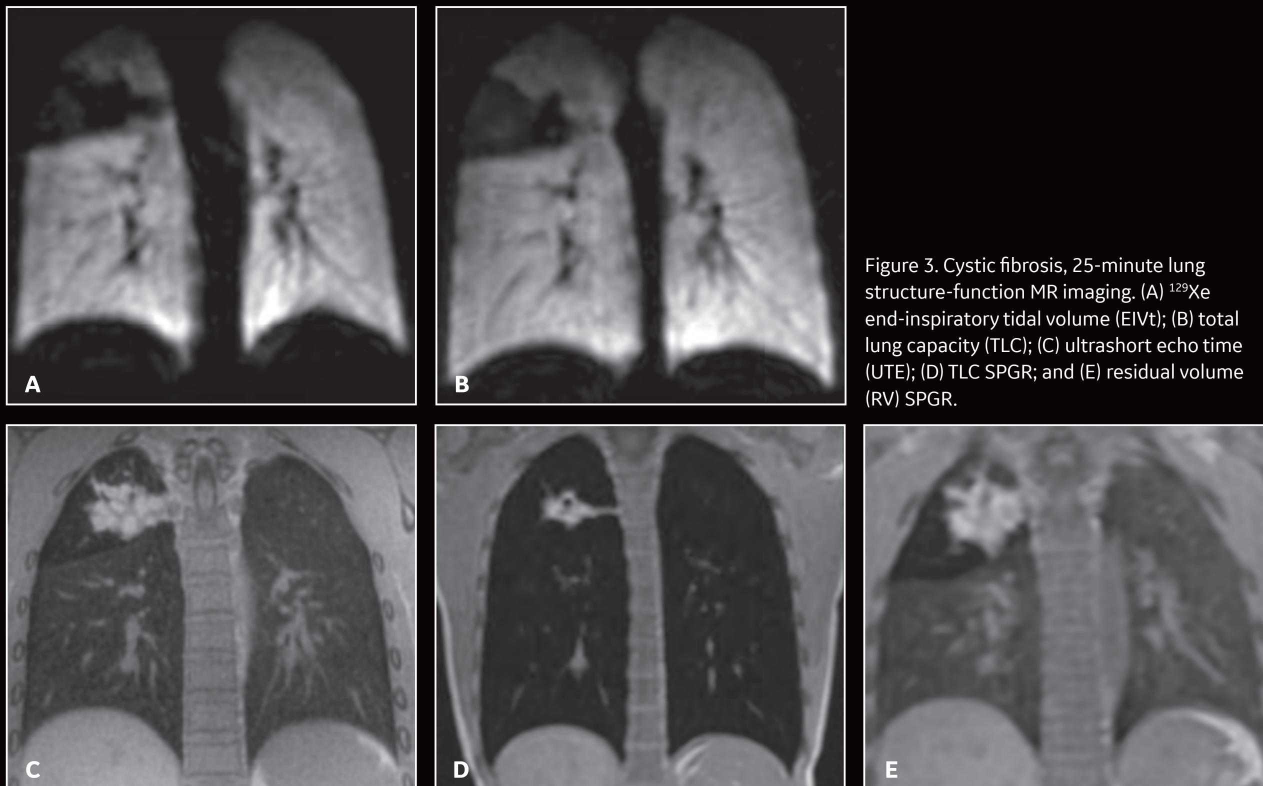

Figure 3. Cystic fibrosis, 25-minute lung structure-function MR imaging. (A) ^{129}Xe end-inspiratory tidal volume (EIVt); (B) total lung capacity (TLC); (C) ultrashort echo time (UTE); (D) TLC SPGR; and (E) residual volume (RV) SPGR.

carbon monoxide (DLCO) are insensitive to longitudinal physiological changes that can help a clinician assess disease progression and treatment response.[8]

In 20 adult asthma patients treated with a bronchodilating agent, two sets of baseline images using hyperpolarized gas ventilation MR were captured prior to treatment and one set after treatment. Treatment response mapping with hyperpolarized gas lung MR imaging provided regional quantitative information on changes in ventilation, complementing current techniques and providing sensitive outcome measures that cannot be obtained with pulmonary function tests.[9]

"Using the hyperpolarized gas lung MR technique, we could assess treatment response and monitor how specific parts of the lung responded to the inhaled therapy," Professor Wild says. "We have a methodology that is safe, repeatable and robust with added sensitivity to the early signs of lung disease and small changes in response to therapy."

In addition, Professor Wild also believes the technique could be used by pharmaceutical companies in early drug design trials for new therapies to treat asthma, COPD and interstitial lung disease.

He adds, "The ability to monitor change before existing lung function testing is where this technology is really making a difference in respiratory disease." S

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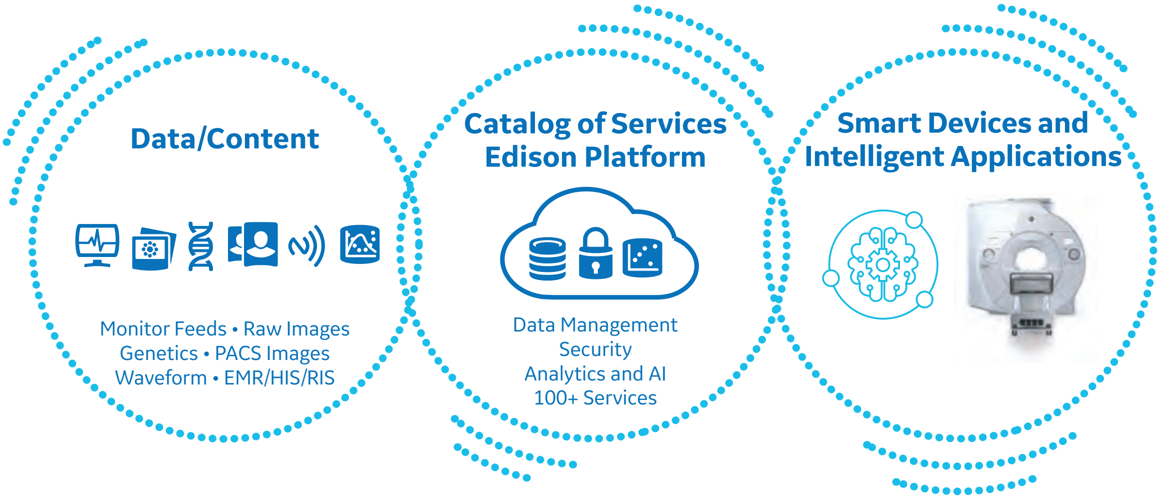
Edison a common, integrated digital platform for AI



GE Healthcare's vision for precision health is to enable the right outcome, for the right patient, delivered at precisely the right point of care. Edison is GE's intelligence offering comprised of applications and smart devices built to help enable this vision.

GE has been investing in digital and artificial intelligence for many years. Edison is part of GE's $1 billion and growing Digital portfolio and will serve as a "digital thread" for its existing artificial intelligence partnerships and products.

Edison provides one common platform to build both descriptive (business intelligence) and prescriptive (artificial intelligence) applications. The platform is a holistic and integrated digital platform for healthcare, combining globally diverse data sets from across modalities, vendors, healthcare networks and life sciences settings. Edison enables continuous innovation to GE's installed base, a common platform that will enable multimodality orchestration of data, giving clinicians access to insights for each individual patient using all relevant data sources, and a modern software architecture that accelerates the development of advanced intelligent applications

This advanced intelligence platform is the foundation for building applications and devices that will help radiologists get faster access to better clinical insights, workflow improvements and the latest innovations. Edison is comprised of applications (Edison Applications), devices (Edison Smart Devices) and developer services (Edison Platform).

Edison Applications are a set of applications developed by GE and clinical partners that deliver analytics and artificial intelligence across GE devices. These applications derive intelligence from data and content, providing healthcare providers with actionable insights to enhance and augment their clinical, financial and operational decision-making.

In MR, these applications include:

- Intelligent SAR management, developed with a machine learning (ML) algorithm for fast and accurate SAR estimates
- ViosWorks, powered by Arterys™, a comprehensive cardiac MR analysis accelerated by AI, including 4D Flow, with deep learning (DL) based automated segmentation. ViosWorks leverage the learning analytic power of the cloud.
- cmr^{42} analysis, a DL-based contour detection for comprehensive cardiac MR analysis on the AW or AW Server.
- Quantib Brain, an automatic labeling, visualization and volumetric quantification of brain structures that uses ML-based automatic segmentation of brain tissues and white matter hyperintensities.
- Liver AI, powered by Arterys™, a DL-powered volumetric segmentation and longitudinal tracking of liver lesions according to LI-RADS® scoring.

An example of Edison Intelligent Applications is **AI**Rx™‡, GE's intelligent MR slice prescription designed to help technologists determine the best position for the slices. AIRx™ rapidly identifies anatomical landmarks and helps deliver consistent and accurate scans regardless of patient position, time between scans or technologist.

GE's strategy for Intelligent MR is to use patient-adaptive technologies and applied intelligence – artificial intelligence and analytics – to enable precision diagnostics and ensure that the right actions are taken at the right time for each and every patient.

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