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Welcome to the 2018 ISMRM edition of SIGNA™ Pulse of MR. This year is especially meaningful for GE Healthcare as we celebrate 35 years of MR leadership and innovation. We look forward to celebrating this milestone in Paris with our academic and clinical partners, whose ideas, inventions and insights have made this legacy possible.

With this year’s meeting being hosted in the City of Lights, our exhibition will focus on how the “future of MR comes to light.” MR is now available to more people in more places with greater speed and more informed data than ever before, enabling clinicians to provide the best care possible. At ISMRM, we’ll hear from the best and brightest MR minds about where the field is moving scientifically and clinically. And we’ll show our latest portfolio of SIGNA™ products, works in process, and our approach to intelligent MR imaging, highlighting the power of artificial intelligence (AI) to make MR simpler, more consistent and robust. The future of MR is bright.

This year at ISMRM, you will see the next iteration of SIGNA™ solutions including the SIGNA™ Premier. SIGNA™ Premier connects research capabilities with exceptional wide bore 3.0T clinical imaging. Its 146 digital receive channels and SuperG connectome gradient performance enable faster scanning and higher image quality, while maintaining the thermal stability formerly seen only in 60 cm research-class systems. Intelligence is built into the system with new advanced distortion correction for applications like MUSE, producing diffusion-weighted images with image quality resembling T2 images. All of this in a 70 cm wide bore.

To further enhance patient experience, our exclusive, revolutionary AIR Technology Suite of RF coils is designed to help address challenges often encountered by patients and technologists. AIR Technology leverages a unique, flexible conductor that enables the coils to adapt to anatomy, thereby improving signal penetration and SNR. And its miniaturized RF electronics, not only reduce weight and bulk, they also improve isolation between neighboring elements. These benefits provide new degrees of freedom in RF surface coil design; more flexible, higher density designs when compared to conventional RF technology. Like the comfort of a blanket, AIR Technology Coils improve the patient and technologist experience.

SIGNA™ Premier’s 48-channel Head Coil, 30-channel AIR Anterior Array and 60-channel AIR Posterior Array all deliver on the high-density promise, improving SNR, parallel imaging, coverage and overall patient experience during brain, spine, body, cardiac, and whole-body examinations. AIR Technology Coils are currently available on the SIGNA™ Premier and migrating across the SIGNA™ portfolio.

The need to integrate AI into our systems is more important than ever. Our ViosWorks cardiac application uses cloud-based analytics and deep learning algorithms to simplify and accelerate full cardiovascular exams in under 10 minutes. An onboard machine learning algorithm powers our position-dependent SAR management tool making SAR calculations more accurate, leading to reduced scan times. We’re even looking at AI to improve workflow by employing trained neural networks to detect anatomical landmarks for automatic generation of image scan planes. Simply put, we’re making our MR systems smarter, enabling care teams to take action benefiting every patient.

System intelligence also applies to productivity. Our SIGNA™Works productivity platform is fully customizable to help streamline mundane tasks by improving workflow, boosting productivity and minimizing variance in patient care. This impressive portfolio includes our HyperWorks suite of applications: HyperSense, HyperBand and HyperCube, capable of delivering up to eight times faster imaging efficiency. With HyperSense, an acceleration technique, your scans benefit from higher spatial resolution or reduced scan times, enabling faster imaging without the penalties often found in parallel imaging.

These are just a few examples that show how we’re bringing the future of MR to light. For a complete overview, please stop by the GE booth at ISMRM. We look forward to putting these technologies into your hands for research or clinical care, to help you transform healthcare, one patient at a time.

Eric Stahre, President and CEO
Global MR, GE Healthcare

*Compared to conventional coil technology
Study examines accuracy of HyperSense in 3D FLAIR exams of MS patients

A recently published study in the American Journal of Neuroradiology examined the accuracy of a new technique that shortens MR exam times for the detection of multiple sclerosis lesions. HyperSense, introduced by GE Healthcare at the 2016 annual meeting of the Radiological Society of North America (RSNA), is a compressed sensing technique that can reduce scanning time by 30 to 50 percent. The study, “Accuracy of the Compressed Sensing Accelerated 3D-FLAIR Sequence for the Detection of MS Plaques at 3T,” found that by using a compressed sensing factor of 1.3 on a 3.0T MR scanner (Discovery™ MR750), the 3D FLAIR sequence was 27% faster, and it preserved diagnostics for the detection of MS plaques. The study utilized a 32-channel head coil.

Twenty-three consecutive patients with relapse-remitting MS were scanned at Saint Joseph Hospital (Paris, France) using the following protocol: DWI, 3D gradient-echo magnetization-prepared T1-weighted BRAVO, T2 weighted and 3D FLAIR. Contrast was not used. Each patient underwent a 3D FLAIR sequence with and without compressed sensing (HyperSense), acquired in the Sagittal plane with a parallel imaging acceleration factor of 2.

Even with the 27% reduction in scan time for the 3D FLAIR sequence, which translates to a 1:25-minute time savings, the authors reported the diagnostic performance was similar to a conventional FLAIR sequence. A factor of 1.3 for compressed sensing was determined based on the authors’ testing of a wide range of acceleration factors.

Reference

The study appeared online in January, 2018 and can be accessed at: tiny.cc/sps181
Featuring content that covers almost every MR system that GE Healthcare sells, the GE MR Collaboration Community provides access to software development toolkits, comprehensive listings to works-in-progress solutions and a forum for users to share information. GE has simplified the process for sharing software between clinical development partners and provided access to this simplification via the website.

“We want our customers to take advantage of the toolkits, information and learning opportunities,” says Jeff Hopkins, PhD, Principal Engineer, MR PSD. “GE is transforming the way it interacts with customers that are actively working to extend the power of MR imaging.”

What started in 2014 as a forum to help MR users collaborate now attracts one new user every 30 hours. And it is steadily growing, says Hopkins.

“We always envisioned the MR Collaboration Community as a way to share software,” Hopkins adds. “And, it has also become a great way for users to communicate with our engineers.”

The portal also provides an archive of the ever-expanding Q&A section where customers can communicate with their peers. In addition to becoming a site that provides a wide range of technical information, GE hopes that it becomes a forum where clinicians can also share their investigations and experiences. For example, Hopkins says, it could involve a discussion on the optimal sequences for a particular patient case, or customer feedback on optimizing certain sequences and protocols.

Hopkins shares that one customer, located in Canada, recently shared his experience with the online forum. “He told us the forum is something that has been needed for years,” Hopkins recalls. “Anytime that he or a student has a hardware/software question they just post it. He said he has received great solutions given to him from GE and other customers via this mechanism. He even told us that the forum is unquestionably the way to go for researchers to maintain and develop a communication pipeline between GE and other researchers alike.”

Some content may be restricted contingent on formal research agreements with GE Healthcare.
AJNR recognizes MAGiC article as best original research paper accepted in 2017

The American Journal of Neuroradiology (AJNR) named “Synthetic MRI for Clinical Neuroimaging: Results of the Magnetic Resonance image Compilation (MAGiC) Prospectice, Multicenter, Multireader Trial,” as the Lucien Levy Best Research Article for 2017. The award is named for the late AJNR senior editor and Professor of Radiology at The George Washington University who was a champion of establishing the magazine. AJNR’s editor-in-chief and senior editors select an original research paper each year for the award.

The study, led by principle investigator Lawrence N. Tanenbaum, MD, FACR, is the first large, prospective comparison of synthetic MR (MAGiC) compared to conventional MR imaging for routine neuroradiology. 1,526 images read by seven blinded neuroradiologists were performed with prospectively acquired synthetic and conventional brain MR imaging case-control pairs from 109 subjects. Its authors reported that the quality of synthetic MR images were comparable to conventional proton density, STIR and T1- and T2-weighted contrast views across different neurological conditions. They also concluded that the trial supported the use of synthetic MR in neuro imaging to help reduce scan times and patient discomfort while acquiring high-quality diagnostic images.1

Reference

The article originally appeared in the June 2017 issue of AJNR and can be accessed at: tiny.cc/sps183
We believed that MRCP would benefit from employing HyperSense to achieve results in a shorter time,” Dr. Malcolm explains. Over the next few months after the implementation of SIGNA™Works, Dr. Malcolm performed a series of MRCP exams with the existing protocol and also with a new protocol using HyperSense. He alternated between running the old and new protocol first. “I wanted to see if the sequence was reliable and robust and whether it generated new artifacts, resulted in poor imaging or if it could reduce scan times. We started in small increments and compared it in real clinical situations,” Dr. Malcolm adds.

As part of the NHS Foundation Trust, Norfolk and Norwich University Hospital provides comprehensive care to more than 800,000 residents of Norfolk and North Suffolk counties in England. Approximately 1 million outpatient appointments, day-case procedures and inpatient admissions are performed annually across the Trust’s healthcare sites, which include two hospitals: Norfolk and Norwich University Hospital and Cromer and District Hospital.

The Trust has four MR scanners, with three sited at Norfolk and Norwich University Hospital. In December 2016, the hospital’s Discovery™ MR750w, a 3.0T wide bore scanner, was upgraded to the SIGNA™Works productivity platform. This new platform includes an array of imaging solutions that cover a wide variety of contrasts, 2D and 3D volumetric data, motion correction capabilities and the high-efficiency HyperWorks suite with GE Healthcare’s compressed sensing solution, HyperSense. HyperSense is an acceleration technique based on sparse data sampling and iterative reconstruction that enables faster imaging without the penalties commonly found with conventional parallel imaging.

Paul Malcolm, MRCP, FRCR, consultant radiologist, specializes in gynecological and urological imaging with an emphasis on body MR. Dr. Malcolm wanted to explore the new advantages of the SIGNA™Works productivity platform upgrade and believed that one area where HyperSense could make a difference was in MRCP exams.

“We believed that MRCP would benefit from employing HyperSense to achieve results in a shorter time,” Dr. Malcolm explains.

Over the next few months after the implementation of SIGNA™Works, Dr. Malcolm performed a series of MRCP exams with the existing protocol and also with a new protocol using HyperSense. He alternated between running the old and new protocol first. “I wanted to see if the sequence was reliable and robust and whether it generated new artifacts, resulted in poor imaging or if it could reduce scan times. We started in small increments and compared it in real clinical situations,” Dr. Malcolm adds.
Previously, the hospital’s MRCP protocol was acquired in two sequences. The first was a 3D respiratory-triggered, high-resolution sequence that would take approximately four to six minutes. Unfortunately, some larger-sized patients would not tolerate the scan well and in others there would be movement, leading to artifacts. Due to this movement, a second breath-hold radial sequence with thick slices was employed. While this series of rapid, radial scans could be completed in as little as 40 seconds, image quality was limited.

After comparing approximately 30 MRCP cases, Dr. Malcolm felt he had sufficient imaging data to assess the clinical value of HyperSense. While evaluating if HyperSense could be used to shorten the respiratory-triggered sequences, Dr. Malcolm found several advantages.

First, by using a HyperSense factor of 1.6, he could generate similar image quality in the high-resolution, respiratory-triggered sequence in about two-thirds the time, sometimes less. The next step was to evaluate the breath-hold sequence with and without HyperSense. By using HyperSense, this sequence could be reduced to 25 seconds with very high image quality.

“When we compared the faster sequence using HyperSense, the image quality was similar. That is a substantial gain. Just as important, when we ran the faster scan with HyperSense, the patient could better tolerate the sequence and did not move as much. Sometimes with the conventional breath-hold radial sequence we would get a non-diagnostic scan with movement. But with HyperSense, we could obtain a diagnostic scan and get a result where previously we couldn’t.”

Dr. Paul Malcolm

Figure 1. A 50-year-old female with a prior cholecystectomy and elevated bilirubin was referred for MR to determine the presence of a common duct abnormality. (A) Conventional MRCP with respiratory-triggered sequence in scan time of 6:10 min compared to (B) MRCP with HyperSense factor of 1.6 in 3:33 min, representing a 45% reduction in scan time. Note the comparable image quality.
Figure 2. A 47-year-old male with primary sclerosing cholangitis and cirrhosis of the liver. Patient was claustrophobic and couldn’t tolerate a second 3D respiratory-triggered sequence. (A) Conventional MRCP with respiratory-triggered sequence was acquired in 5:41 min. (B) HyperSense was employed with the fast breath-hold radial sequence with a scan time of 25 sec.

Figure 3. A 50-year-old claustrophobic male with gallstones, abnormal liver function test and pancreatitis. (A) Conventional 3D respiratory-triggered in scan time of 5:51 min; (B) 3D respiratory-triggered HyperSense in scan time of 2:31 min; (C) breath-hold radial HyperSense in scan time of 25 sec.
“In the acquisition plane, we achieved similar image quality with the breath-hold HyperSense when compared to the 3D respiratory-triggered sequence,” Dr. Malcolm explains. “While the spatial resolution wasn’t the same, the 3D breath-hold HyperSense sequence could often provide the information that we needed for a confident diagnosis. So, even if the patient couldn’t tolerate the high-resolution 3D scan, the breath-hold HyperSense scan alone often resulted in a successful examination.

“We were able to move from a situation where we had limited information from a breath-hold radial sequence to an MRCP study that provides us with the information we need to make a diagnosis. HyperSense has significantly improved our imaging ability and reduced our imaging scan times, thus increasing the proportion of patients in whom we can obtain a quality diagnostic MRCP study.

As a result, the MRCP MR imaging exams at Norfolk and Norwich University Hospital have now been modified to always include HyperSense. Parallel imaging is also being used with HyperSense to gain the maximum benefit of both; yet, the technologists don’t have to push the limits of using parallel imaging and avoid the signal loss that would otherwise occur.

While the preference is to always collect the 3D respiratory-triggered sequence with HyperSense, Dr. Malcolm knows that he has a back-up sequence with the breath-hold HyperSense scan. Although the time-saving benefits using HyperSense are obviously important, the fact that Dr. Malcolm can acquire diagnostic exams on patients who move or are claustrophobic—and typically have non-diagnostic MR studies—is significant.

With nearly two minutes saved per patient in MRCP cases, Dr. Malcolm and the department have gained added flexibility in patient scheduling.

“With this flexibility, we can squeeze in cases where we couldn’t have done that before,” he adds.

The technologists are also pleased with the time savings. They would often try to reduce scanning time, especially in claustrophobic or obese patients where the possibility of a non-diagnostic scan was higher. Now, with HyperSense, they have an increased chance for success.

Next, Dr. Malcolm intends to evaluate the use of HyperSense in other areas such as vascular imaging where HyperSense has the potential for time savings without loss of quality and can enable diagnostic studies in more challenging patients.

Dr. Paul Malcolm
MR is known for its range of soft tissue contrasts to depict anatomy in greater detail and its high sensitivity and specificity for brain abnormalities, lesions and injuries. CT is often used for acute and trauma cases due to its inherent speed. “Time is brain” in clinical imaging and therefore CT is often the modality of choice.

However, recent advancements in MR scanner technology—gradients, sequences and coils—have reduced scan times and also improved sensitivity. Fast MR pulse sequences and the utilization of compressed sensing, i.e., HyperSense, have helped close the time gap between CT and MR leading to greater utilization of MR in acute cases.

At Gyeongsang National University Changwon Hospital (GNUCH) in South Korea, Hye Jin Baek, MD, PhD, Associate Professor, and colleagues have been routinely using 3D FLAIR with HyperSense on SIGNA™ Architect for routine neuro imaging, including cranial nerve (IAC protocol) and brachial plexus imaging. Prof. Baek and her colleagues have also developed a two-minute neuro protocol for acute cases by utilizing HyperSense and HyperBand (see SIGNA™ Pulse of MR, November 2017 issue, pages 55-57).

Preferred sequences for MR neuro imaging at GNUCH include MAGIC, Time-of-Flight (TOF) MRA with HyperSense, 3D FLAIR with HyperSense, 3D T2 Cube, 3D FLAIR Cube and HyperCube with Flex. Prof. Baek recently conducted a 4-point Likert scale survey of colleagues to determine their satisfaction with the image quality of these new neuro imaging techniques: 1 = inadequate; 2 = sufficient; 3 = good (acceptable for diagnostic use); and 4 = excellent. MAGIC was rated as 3 while all other techniques received a score of 4.

“3D images provide ancillary information regarding anatomical details and lesion characteristics during a single scan because 3D sequences help to overcome inherent limitations related to the spatial resolution of 2D images, which are generated only in one plane during a single scan,” Prof. Baek explains. In her experience, and similar to reports by other researchers, synthetic T2 FLAIR has a marginal hyperintensity along the brain surface. However, Prof. Baek believes this does not have a significant impact on diagnosis.

Prof. Baek uses MAGIC to acquire all the basic contrasts in a reduced scan time. Then, by adding 3D FLAIR, she can acquire high-resolution, thin-slice images that can be post-processed into any plane. This approach provides her with a more comprehensive view of the patient’s anatomy and condition.
“We think the additional acquisition of 3D FLAIR with HyperSense can help enhance a radiologist’s familiarity with synthetic MR during an initial adaptation period.”

Prof. Hye Jin Baek
According to Prof. Baek, the ability to reduce scan time with HyperSense delivers additional patient and clinical benefits. For instance, faster scans can reduce the need for rescanning due to motion artifacts, lessen the need for patient sedation, allow for the acquisition of additional sequences and enable rapid decision-making and the prompt initiation of therapy.

Even advancements in coil technology, such as GE Healthcare’s 48-channel Head Coil, can make a difference. Especially in pediatric patients, it has the effect of improving the image quality of synthetic MR and intracranial MRA,” she explains. “Additionally, patients who have been scanned with this coil have said it is more comfortable than other MR head coils they have previously experienced.”

Prof. Baek believes that continued research and development in compressed sensing and 3D neuro imaging could help increase its utilization.

“Brain tissue is vulnerable to some insults such as ischemic stroke or trauma; therefore, rapid evaluation is very important. These techniques—HyperSense, HyperCube, 3D FLAIR, etc.—can reduce scan time and enhance image quality to aid in rapid diagnosis that assists with the appropriate management of patients.”

Prof. Hye Jin Baek

Figure 2. In this case, the addition of 3D FLAIR with high-resolution, thin-slice imaging that can be post-processed into any plane enabled the detection of a neurogenic tumor in the inferior ganglion of vagus nerve and neurogenic tumor in the inferior alveolar nerve. Prof. Baek believes that both Axial and Coronal images are important to visualize the nerve anatomy. The scan time for the 3D FLAIR with HyperSense was 3:30 min.
“There is a need for further improvements in MR acquisition speed and greater access to availability because MR is a very sensitive modality for lesion detection and differentiation in the field of neuroradiology,” Prof. Baek explains. “In addition, as imaging technology evolves, more detailed anatomical information is required, and there is also an increasing need to quantify and characterize specific anatomy.”

Figure 3. Comparison of (A-C) a routine 3D TOF with HyperSense in a scan time of 3:10 min with (D-F) the ultra-fast 3D TOF with HyperSense (developed at GNUCH) in a scan time of 38 sec.
Emory Johns Creek Hospital elevates performance and patient satisfaction with SIGNA Artist

Located 40 miles north of Atlanta, Emory Johns Creek Hospital is one of six hospitals affiliated with Emory Healthcare, the region’s most comprehensive academic health system. The hospital recently installed the SIGNA™ Artist 1.5T MR system, replacing an older 1.5T system originally installed when the site opened in 2007.

For Emory Johns Creek Hospital, upgrading their MR technology wasn’t about being a “pioneer”—it was about implementing a system that would serve the 200-bed hospital with more speed and high-quality imaging than what they had before.

“SIGNA” Artist brought us a long way from our previous platform,” says Chrystal Barnes, CRA, RT(R)(CT), Director of Imaging at Emory Johns Creek Hospital.

“I just wanted to provide an upgrade in technology and quality to this hospital. GE Healthcare jumped in to provide all the software solutions we needed, and they worked with our physicians and technologists to ensure we maximized the technology. They leaped over the moon for us.”

An upgrade in service
Barnes considered quotes from two vendors and paid particular attention to service capabilities. “GE provided everything we needed and then some,” she says. “As an example, when I ask GE for a protocol, and they drive over to install that protocol in between patients, that’s a wonderful example of going above and beyond.”

Since installing the system, the service has continued to exceed expectations. “It’s the best service that I’ve had in almost 40 years in radiology,” she says.
Puneet Sharma, PhD, Assistant Professor, Department of Radiology and Imaging Sciences at Emory University, enjoys having GE’s expert advice on hand for insight and collaboration. “They know the tips and tricks behind the sequences. We may know the theory, from research and literature, but it’s good to have vendor experts on-site who know the software and system better than we do.”

**Consistent protocols**
The Emory health system’s overarching strategy is to standardize protocols across sites—a significant challenge due to the geographical spread, different software systems and mix of vendors at each location. Despite these complexities, the SIGNA™ Artist helped Emory Johns Creek Hospital establish protocols consistent with the main Emory campus.

“I felt confident propagating a lot of the protocols from Emory to Johns Creek, and it has been a pretty easy transition. With the SIGNA™ Artist, it was a pleasure to be able to easily replicate, almost one-for-one, sequences from the main campus to the system,” says Dr. Sharma.

This process was a significant improvement over past experiences, and it has brought Emory Johns Creek Hospital to the forefront of technology across the different Emory sites. “In the past, I had to compromise on some of the sequences I selected on older models in our fleet, which diminished the radiologists’ use of that particular system. Now I see it as a level playing field.”

**Powerful applications**
With SIGNA™Works innovative applications like HyperCube and HyperSense, SIGNA™ Artist empowers Emory Johns Creek Hospital to deliver improved image quality, higher efficiency and a more streamlined workflow.

HyperCube expands the capabilities of 3D imaging to significantly reduce scan times and minimize artifacts by reducing the phase field-of-view (FOV) without the presence of aliasing artifacts. HyperSense is an acceleration technique based on sparse data sampling and iterative reconstruction that delivers higher spatial resolution images or reduced scan times, enabling faster imaging without the penalties commonly found with conventional parallel imaging.
High-resolution T2 imaging was previously a challenge on the prior MR system. Emory Johns Creek Hospital has begun using HyperSense with HyperCube for 3D imaging in neuro, body and pelvis scans. Dr. Sharma estimates the application has decreased scan time by 20-30% on average.

“There’s been a significant drop in scan time. That is definitely one of the highlights. With HyperSense, we can achieve the same image quality in pelvis studies in almost half the time compared to other sites. Our goal is to run all of our T2 Cube imaging with HyperSense and/or HyperCube and all of our Time-of-Flight studies with the HyperSense version.”

Dr. Puneet Sharma

The full 50 x 50 x 50 cm FOV in the 70 cm wide bore is another benefit, allowing Emory Johns Creek Hospital to more efficiently complete imaging exams that combine multiple stations, such as the chest, abdomen and pelvis. This, in turn, allows them to keep more exams in-house, rather than send them to the main Emory campus in Atlanta. In fact, abdomen-pelvis exams represent close to 50% of the body MR exams across all Emory sites. Previously, if these cases were not referred to the main campus, they would be split into separate exams at Emory Johns Creek, such as abdomen one day and then pelvis another day.

“We are able to do exams we couldn’t do before, and now we can do these exams efficiently,” says Dr. Sharma. And, that is also good for patients, who no longer have to travel longer distances or undergo two different MR exams for a large FOV study.

He also notes the newer body array coils are a tremendous improvement, with more signal sensitivity and more coverage, which has made a significant difference in breast MR exams. Plus, with the addition of VIBRANT Flex and HyperSense in the SIGNA™Works portfolio, the technologists can acquire homogeneous fat separation in a single 3D volume scan that delivers water-only, fat-only, in-phase and out-of-phase images of the breast.

For the patient
SIGNA™ Artist has also helped improve staff and patient satisfaction rates.

The hospital streamlined redundant tasks with automated tools like auto breath-hold and the propagation of imaging parameters. In addition to the clean interface and easy-to-navigate system, it has made technologists’ jobs easier. For example, the in-line post-processing tools have helped speed up the technologists’ workflow.

“If you give staff the right tools to do their jobs, they become very happy people. Giving them SIGNA™ Artist was like handing them a treasure,” says Barnes. “They have the ability to add patients in between scheduled exams because it’s faster. That takes stress off the shoulders of my staff and therefore makes them happier.”

Figure 3. (A) T2 Flex HyperCube bilateral breast exam with HyperSense factor of 1.3 in a scan time of 3:37 min; (B) VIBRANT Flex.
Another factor is patient comfort, which directly affects patient satisfaction scores. Emory Johns Creek Hospital built a new suite around the SIGNA™ Artist to give patients a better overall experience. Now the site’s Press Ganey scores have increased from single digits to the mid-90s. “It’s a dramatic turnaround from where we were before. Patients are commenting, ‘I come here often, and this is the fastest I’ve ever gotten out of here,’” says Barnes. “It’s considerably faster than what we had in the past.”

The SIGNA™ Artist’s 70 cm wide bore design helps alleviate a patient’s fear of entering the MR bore. The expansive diameter, soft lighting and soothing fans help ease patient anxieties and concerns. The wider table design sits lower to the ground, enabling easier patient positioning. Lightweight and adaptable coil designs conform gently to a patient’s anatomy, elevating the patient experience. The SIGNA™ Artist’s eXpress table, with a memory foam surface, delivers feet-first or head-first imaging and features a detachable egress and IntelliTouch positioning.

“The whole experience moves us toward the ultimate goal of a spa-like experience for patients,” says Dr. Sharma. “SIGNA™ Artist is certainly progress toward that goal, and it’s good to see GE Healthcare continuing to innovate the way forward on that.”

Figure 4. (A) Brachial plexus exam; Coronal T2 Flex with HyperCube and HyperSense factor of 1.3 in a scan time of 3:12 min. Prior to HyperSense, this scan would not be acquired due to the length of the scan. (B) Same brachial plexus exam as (A), reformatted to demonstrate the full length of the nerve root. (C) A patient with metastatic cancer that has spread to the vertebral bodies; multi-weighted total spine exam using Flex, pasted for full coverage.
An efficient and reproducible toolset for cardiac MR image analysis

Recent advances in cardiac MR imaging and post-processing capabilities, such as higher spatial-temporal resolution and accelerated cardiac exam workflows, have reinvigorated its use in clinical practice. To address this growing need, GE Healthcare announced the integration of cmr42 cardiovascular post-processing software, licensed from Circle Cardiovascular Imaging (Calgary, Alberta, Canada), onto its GE Advantage Workstation (AW) and AW Server. cmr42 is state-of-the-art software that delivers a comprehensive toolset for cardiovascular MR image analysis, including features such as automated contour definition, quick-editing tools and synchronized viewing schemes that simplify tasks commonly done manually. It contains a broad suite of advanced, easy-to-use modules for viewing and analyzing cardiac MR images, including heart function, flow, tissue characterization and T1 mapping and tissue parametric mapping (T2/T2*).

Matthew T. Bramlet, MD, the Director of Congenital Cardiac MRI at Children’s Hospital of Illinois and an Assistant Professor of Pediatrics at the University of Illinois College of Medicine at Peoria, has been using cmr42 as his cardiac MR post-processing software tool for several years. As a pediatric cardiologist, he specializes in children with congenital heart disease, a disease present at birth where structural heart defects involving the heart muscle, valves and/or associated arteries and veins disrupt the normal flow of blood through the heart. For example, blood can flow in the wrong direction or to the wrong place, with varying impact to the patient’s health depending on the severity of blood flow disruption. Accurately measuring heart morphology and blood flow is critical for proper diagnosis and treatment planning of congenital heart disease. Fortunately, since the human cardiovascular system is a closed system of heart and blood vessels, certain cardiovascular relationships must hold true, which offers the possibility of internal validation when performing volume and flow measurements—in other words, the “numbers must match.”

“cmr42 is valuable because it is an efficient and reproducible tool that allows me to standardize how to validate the numbers I provide in my reports,” Dr. Bramlet says.

“When calculating left and right ventricle numbers, I want to have greater confidence in the volumetric analysis and diastolic volumes. By using a reproducible tool, I’m confident that my numbers match.”

Dr. Matthew Bramlet
In particular, the thresholding segmentation contouring tool in cmr42 is easy to use on congenital exams with a quick click-n-drag mouse action that facilitates his ability to achieve the same level of thresholding in each imaging slice, and therefore generates reproducible values. With cmr42, Dr. Bramlet can apply the threshold and have a high level of confidence that the values are accurate on each slice.

When tracking the endomyocardial border, it is possible to lose the border when a ventricular trabeculation and compaction comes together. Yet, with the thresholding tool, Dr. Bramlet says he can “dive down into where the endocardium is located in a unified fashion, based on minor variations and signal intensity, and feel more confident visually when looking at ejection fraction and the right ventricle that it matches the left ventricle.”

In cases of Tetralogy of Fallot, a common congenital anomaly, Dr. Bramlet uses the software to quantify right heart flow and volume. The regurgitant flow fraction measured at the pulmonary valve should match the left and right ventricular volumes. When these numbers do match, he is then confident providing the value to the surgical team for their decision-making process.

As an example, in the case of a 5-year-old patient with pulmonary regurgitation and volume overload on the right ventricle, he uses cmr42 to calculate the end-diastolic right ventricular volume just before systole. This value is often used by institutions to determine when a patient should undergo pulmonary valve replacement surgery.

“I want to derive that volume not just from a single analysis but one that is validated elsewhere in the patient imaging data,” Dr. Bramlet says. “In a typical patient study, in addition to the right and left ventricular analysis, I will..."
include aortic and pulmonary phase contrast sequences, which allow me to correlate these values. The regurgitant fraction from the pulmonary valve will frequently relate to the left ventricle and right ventricle. When these values match up, then I am more confident it is a true representation.”

Dr. Bramlet finds cmr42 is not only easier and more reproducible, but it is also faster with more reliable values. “cmr42 values are consistent with the clinical picture and easy and efficient to obtain,” Dr. Bramlet adds.

In clinical practice, Dr. Bramlet will first launch the 4D viewer for an overview of the case and the volumetric display. He uses the subtracted series from TRICKS and selects a time-resolved image to render (Figure 1). Next, he finds a third subtraction series, and loads the right side of the heart structures for an ideal representation of the organ. He then processes a 3D volumetric map for visualization purposes only (no measurements) and creates a rotating cine image.

“If the tools (in cmr42) allow me to move faster through the slices and image series, and facilitate movement and actions during the data manipulation so that it is more reliable. I measure the descending aorta every time for extra confidence and by doing that I feel I’ve gained more knowledge on the patient’s condition.”

Dr. Matthew Bramlet

The Tissue Characterization Module is only available for research purposes in the USA since the use of contrast agents for Cardiac MR procedures is not FDA approved, and should not be used clinically.

Figure 2. Patient with Tetralogy of Fallot: The flow values are important in patients with coarctation of the aorta. Selecting the ascending and descending aorta generates additional data that can be used as an internal control to validate the flow data.
Tom Cappas, MBA, MS, RT(R)(MR)ARRT,
Director of Radiology, that the time to
invest in 3.0T was now.

Cappas set out to develop a business
plan to support a 3.0T MR acquisition.
There were several business-related
challenges that 3.0T MR could help the
practice overcome. First, by adding a
3.0T MR, the practice could begin to
attract referrals from urologists for
prostate imaging. Second, orthopedic
surgeons were interested in referring
complex cases to 3.0T rather than 1.5T.
And, third, advanced neuro imaging
utilizing novel new sequences often
require the higher field strength.

As with all new system procurements,
Cappas sent out a request for proposal
to all the major MR manufacturers.
While historically the organization
turned to a competitor for its MR
systems, this time was different.

For over 60 years, MidState Radiology Associates, LLC has been a leader in
diagnostic and therapeutic radiology for the residents of Connecticut. The
practice is renowned for providing high-quality subspecialty care in both
acute and outpatient healthcare settings. In addition to providing services
at three hospitals—MidState Medical Center and the Hospital of Central
Connecticut, which is comprised of two separate facilities—the group also
owns and operates nine outpatient imaging centers.

MidState Radiology Associates
provides imaging services across
a broad array of specialties—
women’s imaging, interventional,
neuroradiology, oncologic/body imaging,
musculoskeletal, orthopedic and
sports medicine—with nine 1.5T MR
systems across the 12 sites. When
two new subspecialized radiologists
joined the practice—an MSK and
neuroradiologist—they convinced

GE MR
applications
training ramps up
productivity... even on
day one
“When planning to procure an MR system, you have to look 15 years down the line and we saw the path for the 3.0T product lifecycle with GE,” Cappas says. “We took notice of the significant investment in research and development by GE Healthcare and realized they were leaps and bounds ahead of the competition. That was the key differentiator for us.”

Yet, there was one key concern for Cappas and his team: SIGNA™ Pioneer would be the organization’s first GE MR system and that could present a significant challenge for implementation, training and day-to-day operation.

**Wing-to-wing support**

From the start, Cappas expressed to the GE team his concern regarding the transition from one MR manufacturer to another. “I was assured from the beginning that the entire process would be quarterbacked by GE, wing-to-wing. They’ve exceeded our expectations.”

Nicole Cari, BS RT(R)(MR)ARRT, Lead MR Technologist at MidState Radiology Associates, was at first nervous about learning a new system from a new vendor. So, she participated in online applications courses, which provided a basic knowledge of GE MR with clear language and learning objectives.

“The sales and applications team worked seamlessly together to create a smooth transition. They were both very attentive to my needs as a customer and a lead technologist. Not being initially involved in the sales aspect, I was hesitant to reach out; they were more than friendly and helpful,” Cari says. She also found the GE applications team to be very understanding and helpful regarding her and her technologists’ lack of experience with a 3.0T MR system.

The existing 1.5T protocols were provided to GE as a starting point. The team from MidState Radiology Associates, with GE clinical applications support and guidance, made some changes on the protocols after volunteer scanning.

Figure 1. A 30-year-old female presented with a lump on the lateral aspect of the right midfoot. The area is painful to touch and swells with overuse. No prior surgery or injury reported. T1, T2 FatSat, and PD FatSat FSE-weighted scans were obtained in the Axial, Sagittal and Coronal planes. Study demonstrated a 1.6 cm dorsal lateral midfoot perilarticular ganglion extending from the lateral cuneiform cuboid articulation with overlying extensor digitorum brevis intramuscular and perimuscular edema.
Making an impact

A key aspect of Cappas’ business plan was to demonstrate a growth in imaging procedures that would help MidState Radiology Associates generate a return on investment (ROI). The growth would come from not losing referrals to other 3.0T MR scanners in the area as well as the ability to attract new referrals through new imaging capabilities.

A few days after the installation, Cappas says the scanner was back up to a normal scanning workload—a feat that often takes up to three weeks. Not only has SIGNA™ Pioneer outperformed Cappas’ projections, new imaging sequences are further elevating the quality of care.

“We installed SIGNA™ Pioneer in June 2017 and have experienced tremendous success. We successfully built our top 10 protocols and learned what the SIGNA™ Pioneer was capable of, all prior to the installation,” Cari adds. “This was extremely helpful in the turnover from not only 1.5T to 3.0T, but also switching vendors.”

For Cappas, the most important aspect of GE applications training was the fact that the protocols were optimized outside of the clinical environment. “In all my years, I had never seen this approach,” he says. “It was crucial to enable us to start scanning patients on day one. It was remarkable how easy it was.”

30 days prior to the implementation, Cappas saw his team was anxious regarding the SIGNA™ Pioneer implementation. However, as the install date drew near and the team received training and applications support online and on-site, he witnessed a calming and confidence he hadn’t seen before.

“What GE did really well was to prepare the staff, which allowed them to take full benefit of the technology,” Cappas says. “My technologists are bragging about the system’s capabilities.” He notes that there are older scanners that the team does not fully maximize the benefits of because the applications training was only held on site with the added pressure of having to scan patients.

Cari adds, “Being able to scan patients on the first day would not have been possible without GE’s attention to detail and thorough education process, from online modules to applications and on-site training.”
growth,” Cappas says. “We are up 17% over the same period from the prior year.” Considering he projected flat growth in year one and 3% growth in years two through four, the increase in imaging studies is having a significant impact on ROI.

A new orthopedic practice has started referring all its patients to MidState Radiology Associates. The volume is so significant that MidState Radiology Associates holds a certain number of time slots for the orthopedic practice. The group has also launched its prostate imaging service and in the first seven months performed 97 prostate MR exams. They have also marketed SilentScan to attract more neuro imaging referrals and received new body imaging referrals from an in-network radiology group with the addition of FOCUS DWI for diffusion body imaging.

Clinically, the radiologists have a new upper limit threshold for visualizing anatomy.

“We were convinced the technology was there, however, we underestimated the level of detail and ability to recognize the most intricate structures that we were never able to visualize before,” says Gary Dee, MD, President, MidState Radiology Associates. “The level of detail has allowed us to not turn away exams due to a lack of confidence in not being able to see certain structures and subsequent pathologies.”

In addition to the growth in prostate imaging referrals, Dr. Dee adds that the practice has increased the volume of small extremity, nerve, cardiac flow and neurologic exams. For example, SilentScan made a significant impact on imaging patients referred for chronic headaches and movement disorders referred from a local neuroscience institute.

“The feedback from the patients has been tremendous,” Dr. Dee says.

Dr. Dee also sees the value of FOCUS DWI. “FOCUS DWI is a great technique for imaging in the prostate. Overall, the image quality helps us see things we never saw before... the hardware and software are phenomenal. The best part is that GE is proud of their technology and shows us how to make the most of it.”

In terms of overall scanning and capabilities, Cari and her technologists find the interface and software to be very user friendly. Even small things such as a list of acronyms that Cari can use as a guide made her experience that much easier. Yet, it’s the sequences that really impress her the most.

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Figure 3. A 60-year-old male presented with left ankle pain following a tennis injury. PD, PD FatSat, T1 and T2 FatSat FSE-weighted scans were obtained in the Axial, Sagittal and Coronal planes. The study demonstrated a complete Achilles tendon tear approximately 6 cm above the posterior calcaneal tuberosity with a 1.5 cm gap at the site of the tear. The proximal tendon remnant was heterogeneous and irregular, associated with intratendinous, perifascial and intramuscular edema in the distal soleus. There was extensive soft tissue edema surrounding the ankle. The anterior talofibular ligament was torn.
It’s that partnership approach that gives Cappas peace of mind that he and the clinical partners made the right decision selecting GE and SIGNA™ Pioneer. "With all the applications support, our technologists feel like they are in a partnership and not on an island by themselves. Our radiologists love that they can deliver more detailed reads and greater clarity in their reports due to the increase in image quality. And while I was concerned about the move to a different manufacturer, with GE I have an entire team behind us. Add to that their great technology, and I feel we have a competitive advantage in our market."

“I’m now a big fan of the Cube sequence—the 3D isotropic volume imaging is gorgeous,” she says. “Both the technologists and neuroradiologists are blown away by the 3D Inhance. I am equally impressed by the fat saturation techniques; the IDEAL sequences in the soft tissue neck and orbits are great alternatives in areas where fat saturation is often hard to obtain.”

Ease of positioning the lightweight Flex Coils exceed expectations. Not only are these coils easier to position, they are more comfortable for the patients. “The signal is amazing and we definitely tested their ability with our MSK imaging,” Cari adds. “Overall, I just can’t say enough good things about GE. Everyone—sales, applications and engineers—are all so attentive and quick to respond.”

Dr. Dee agrees, adding that other sites seeking to add or replace a MR scanner should look closely at the investment GE has made in R&D. “The GE team has a total solution with wing-to-wing support that will exceed expectations, especially during a conversion from one manufacturer to GE. We have a partner in MR that will enable us to make the best use of their cutting-edge technology.”

MR Imaging Academy

Through GE Healthcare’s Imaging Academy, applications training is a blended learning approach using diverse delivery mechanisms and multimedia tools that work to set expectations and prepare each facility’s team to optimize this valuable time. From on-site training that begins before the installation to ongoing, post-implementation education, GE is committed to helping each facility optimize MR system capabilities and elevate patient care quality.

GE’s blended approach for skill building includes:
- Web-based, self-paced learning modules that build foundational clinical knowledge and offers CE credits
- Classes at GE Headquarters featuring hands-on scanning in a state-of-the-art facility
- On-site hands-on training with a site-customized agenda and image quality review
- Ongoing, post-implementation education with remote instructor-led training, access to clinical experts through the TiP Answer Line and on-demand resources such as webinars, quick guides, videos and more.

To learn more about GE MR training opportunities, contact your local GE Healthcare representative or visit www.gehealthcare.com/applications.
Fast protocol with 3.0T breast MR helps improve exam speed and patient satisfaction

For many women, getting a mammogram is like going to the dentist.

“No one wants to do it even though they know it’s important,” says Shakira Sarquis-Kolber, Director of Women’s Imaging at Christine E. Lynn Women’s Health & Wellness Institute at Boca Raton Regional Hospital in Florida. “So, we recognized the apprehension and decided to make a change. We can’t change the exam, but we can change their experience. Distracting them by engaging them in what’s happening around them rather than what’s happening to them lets them walk away with a better experience.”

The Christine E. Lynn Women’s Health & Wellness Institute provides women with a continuum of care that addresses their unique medical needs throughout their life cycles. The 46,000-square-foot facility offers the expertise of renowned clinicians, the most advanced imaging technology in the region and myriad holistic and educational programs, as well as support groups. In fact, women played an integral role in the design and construction—with a woman as the lead architect and general contractor.

The institute recently replaced its 1.5T MR with a Discovery™ MR750w 3.0T system, housed in the newly opened Ellman Family Center for Imaging. With this, the institute has developed into the area’s premier and most preferred breast program, performing nearly 100,000 screening and diagnostic procedures a year. The Schmidt Family Center for Breast Care boasts an array of GE Healthcare imaging equipment, from digital breast tomosynthesis, molecular breast imaging and contrast enhanced spectral mammography.

“When making a decision on how to expand, we included everyone—technologists, radiologists and even biomedics. And GE won,” says Kathy Schilling, MD, Medical Director at the Institute. “For me, it’s important to have uniformity of equipment for utilization to improve efficiency in the department. Let’s face it, in this business, you have to be efficient to be successful.”

**Fast protocols**

In a tight market, the Discovery™ MR750w 3.0T system gives the center a differentiator. Dr. Schilling notes that women have many choices and facilities need to set themselves apart to not just get their business but gain their trust. One part of that was shortening the long MR exam.

“When we first started performing breast MR, we used the same protocols for high-risk patients as well as to...”
confirm breast cancer in the cohort of patients with a positive screening test," says Dr. Schilling. "But with all other exams, we don’t do that. The screening exam is abbreviated. So, we started to ask why we were doing all of these acquisitions?"

Dr. Schilling also learned about the work that Christiane K. Kuhl, MD, Chair of the Department of Radiology at RWTH Aachen University in Aachen, Germany as well as Ritse Mann, MD of Neimegen, Netherlands were doing in terms of abbreviated breast MR protocols.

The center started its own program to increase breast MR exam efficiency, focusing on fast protocols for newly diagnosed breast cancers and high-risk exams to drive down exam time and costs. By following Drs. Kuhl’s and Mann’s leadership through their published work and working with GE, the center’s protocol now includes T2-weighted Axials, pre-T1-weighted Axials, and three post-contrast acquisitions. They dropped the STIR coronal sequence and reduced the dynamic series by two time points for the diagnostic exam.

The fast protocol cut exam time from 55 minutes to just 25 minutes.

Dr. Schilling also worked with GE to use Time Resolved Imaging of Contrast KineticS (TRICKS) ultra-fast imaging to assist in characterization of the breast lesions (Figure 1).

“We believe TRICKS information is helping us decrease our false positive rate," says Dr. Schilling. “False positives are a known drawback of breast MR. If we can improve our specificity, and I believe TRICKS can help with that, it will be a huge value to our patients and referring clinicians.”

The center is one of the participating sites in a clinical trial, Abbreviated Breast MRI and Digital Tomosynthesis Mammography in Screening Women.
In the first three months of using the new system, the practice reported a significant increase in breast biopsies. They compared previous years’ numbers on the 1.5T system with the new 3.0T system and made another surprising discovery: Total breast MR imaging volume increased 14 percent and biopsies increased 22 percent—but cancers went up 79 percent (Figure 2).

“We were finding more cancers explaining why we were doing more biopsies. On the 1.5T, the positive predictive value of biopsies was 19 percent, which is a little low. On the 3.0T, it went up to 28 percent. It was more accurate in identifying cancers and had fewer false positive findings. That’s really significant for our patients and referring physicians.”

Dr. Kathy Schilling

Beautiful MR images
One challenge presented itself immediately after the MR system was installed, when images showed motion artifacts. After weeks of investigating the scanner, the center discovered a surprising answer. “We listened to the patient. They said, ‘This is so uncomfortable.’ It turns out the issue wasn’t the scanner but the patient repositioning themselves because the coil was uncomfortable during the relatively lengthy exam. It was our ‘ah-ha’ moment,” says Sarquis-Kolber.

They swapped out their coil and now use the GE breast coil which appears to be better tolerated by the patients due to greater comfort experienced. “We moved to the GE coil, and we’ve had beautiful images since then,” says Dr. Schilling.

Figure 2. A 56-year-old woman presented with palpable abnormality five months after negative screening mammography. She was subsequently found to have invasive ductal carcinoma grade 2. Image shown is the MIP MR post neo-adjuvant chemotherapy.
The Schmidt Family Center for Breast Care’s integrated team, in conjunction with the Discovery™ MR750w, allows the center to compress the time it takes to fully identify, diagnose and determine the extent of breast cancer from weeks or months to just 10-14 business days, from screening mammography to surgery.

“The 3.0T improved image quality,” says Sarquis-Kolber. “But more important is the patient experience. If that’s good, then patients are more likely to come in. Whether it’s MR or mammography, it’s a positive experience and a better experience.”

Reference

The patient experience at Lynn Women’s Institute

By Shakira Sarquis-Kolber, Director of Women’s Imaging at Christine E. Lynn Women’s Health & Wellness Institute at Boca Raton Regional Hospital

These words are very meaningful to the team at the Lynn Women’s Institute. It does not mean the speed of the exam or the equipment used. It describes the psychology behind the experience. Breast imaging is set apart from other imaging modalities because of the fear, anxiety and emotion attached to it. Women know they should start having mammograms at the age of 40 and then annually, yet the mammogram’s reputation for being ‘painful’ and the anxiety behind ‘what we will find’ overpowers her will to have the test in many instances. Therefore, the center was designed to provide a calming, serene space that is unlike most imaging centers.

We installed the Senographe Pristina™ mammography system in March 2017, which also improved the patient experience and imaging times as it utilizes a new silver filter. The Senographe Pristina™ design was created to make the mammogram more comfortable for the patients through special features like rounded detector edges, thinner and warmer detectors. With Senographe Pristina™, patients can control their own breast compression, making it a more comfortable experience. First and foremost, it’s faster for patients. They’re in compression less, which makes them happier. Happier patients mean happier techs, and it all equates to improved image quality.

Further complicating screening mammograms is the high number of breast implants in our patient population. The automatic exposure control on the Senographe Pristina™ means the technologists no longer have to calculate the exposure. This results in faster imaging time and consistently appropriate image exposure, which has enabled us to increase screening volume in that room without adding staff. As a result, we now schedule mammography screenings for women with breast implants in 15-minute slots.

By engaging multiple senses simultaneously, the patient’s psyche is focused on the surroundings, the sounds, the smells, the décor, and not on her perception of impending pain or anxiety. Through the use of the Caring Suite in MR and the SensorySuites in the mammography rooms, patients are subconsciously guided towards being distracted. At the end of their experiences with us, they feel they have had the most comfortable mammogram, ultrasound and MR. So slowly, we feel we are changing the negativity surrounding the discomfort of breast care. Through the design of new equipment and the environment that surrounds them, we are humanizing the patient’s experience, making positive memories so that she won’t be as fearful.
Advanced neuro imaging propels leadership of Darweesh Scan Center across North Africa and the Middle East

Near the banks of the Mediterranean Sea in the heart of Alexandria, Egypt, Darweesh Scan Center is setting new standards for neuro imaging in the Middle East and North Africa. Founded in 1993 by Prof. Reda Darweesh, MD, PhD, and Prof. Soad Kishk, MD, PhD, Darweesh Scan Center is a regional center of excellence renowned for its advanced technology, team of subspecialty clinicians and a strong focus on the patient experience.

Since the center’s inception, MR neuro imaging has dramatically changed from a qualitative diagnostic approach to quantitative imaging. To deliver state-of-the-art imaging services, Prof. Darweesh has invested in advanced technology such as the Discovery™ MR750w GEM 3.0T. Other imaging services available in the center include PET/CT imaging with the Discovery™ IQ, nuclear medicine with Brivo™ NM615 and ultrasound.

“Neuro imaging is rapidly evolving along parallel tracks of applications, acquisition techniques, data processing and informatics. Its quality depends upon the depth and precision of interaction between these tracks, resulting in novel applications for neuroscience research, new biomarkers and advances into clinical use.”

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Prof. Reda Darweesh

Yet across Egypt and Northern Africa, centers that perform advanced neuro imaging services are few and far between. It was this clinical need that spurred Prof. Darweesh to upgrade the level of imaging in his center through technology development, translational research and education.

In fact, the center performs research on autism using MR imaging and anticipates participating in a global study of autistic children in the near future, once the grant funding is secured.

“We see a growing incidence of autism throughout Egypt,” says Prof. Darweesh.

“There is a global recognition of this disorder and the need to better understand the range of conditions on the spectrum. We look forward to the opportunity to participate in global research projects enabled by our investment in advanced imaging technology.”

“We launched our center, Synapse, to specialize in neuro imaging post-processing techniques with the aim to provide more reliable quantitative diagnoses,” he explains. “As technology advances from qualitative to quantitative imaging with high-field MR, our center’s high-quality, multi-modal
neuro protocols help decode the complexity of how the human brain functions in healthy and diseased states.”

As a result of the investment in technology, subspecialty clinicians and advanced, third-party post-processing applications, Darweesh Scan Center is recognized as a regional center of excellence. Patients with neurodegenerative diseases also rely on the center for complex MR examinations that utilize new diagnostic techniques and protocols.

For example, the neuro MR protocol includes: quantitative assessment of brain structure using volumetric analysis; functional connectivity changes detected with resting-state (rs) fMRI; diffusion imaging for visualizing white matter microstructure changes; assessing metabolic changes utilizing MR spectroscopy for metabolite concentration quantification; and quantitative perfusion imaging using 3D Arterial Spin Labeling (ASL).

Dr. Darweesh and his clinical team continue to use conventional MR neuro imaging sequences in patients with neurodegenerative diseases to exclude secondary causes such as vascular lesions or to confirm the absence of specific imaging features.

“Conventional MR, however, has a restricted role in the early detection and follow-up of patients with neurodegenerative disease because it is not sensitive enough to detect the subtle anatomical and functional changes induced by these diseases,” says Mina Rizkallah, MD, a radiologist at Darweesh Scan Center. In some cases, he has seen conventional MR imaging result in normal findings even in patients with known disease.

In cases of patients with Alzheimer’s Disease, a volumetric assessment of the hippocampus and yearly longitudinal tracking helps Prof. Darweesh predict the conversion between mild cognitive impairment to dementia. With 3D ASL, he can quantitatively measure...
Darweesh is hopeful that through precision imaging capabilities and research provided by his center and others around the world, significant advancements in early diagnosis and the utilization of novel treatments will enable better patient management and outcomes.

“Our country is unique in the unfortunate quantity and diversity of neurodegenerative disease cases,” he says. “We have an opportunity to study and share precious clinical data with the global research community and we hope to collaborate with other recognized institutions from around the world.”

References

Multiple sclerosis case study
A 35-year-old female patient was diagnosed with relapsing remitting multiple sclerosis approximately 9 years and 2 months ago.

The patient first came to Darweesh Scan in September 2017 for a baseline MR brain and spine scan. Post-processing volumetric studies were performed and the lesion volumes were recorded at 26.2 cm³ and total grey matter volume was 695207 cm³.

In January 2018, the patient returned to Darweesh Scan for a follow-up study and reported experiencing a two-week period of numbness and tingling in her feet. Based on data acquired in the follow-up MR exam, the lesion locations and volumes were the same; however, the post-processing results indicated a reduction in the volume of total grey matter by about 1.7%, or 683388 cm³ compared to the previous MR exam.

The post-processing technology allows us to see important quantitative volume changes not visible by the naked eye. It is also not possible for such findings to be calculated from conventional MR reporting.

The volume change finding led the referring physician to change treatment to include disease modifying therapy. This kind of precision diagnostics leads to personalized treatment and ultimately better patient care.

At Synapse, part of Darweesh Scan Center, we are optimistic about technological advances in the field of diagnostic imaging and with powerful equipment like GE Healthcare’s Discovery™ MR750w GEM, the image clarity and detail allow us to perform exceptional post-processing techniques and produce quantitative results for our referrers and their patients.
Figure 2. T1 SPGR images of the brain. (A) Baseline scan and (B) follow-up scan.

Figure 3. MR volumetric studies of segmented SPGR help identify lesion volumes in MS patients. (A) Baseline scan and (B) follow-up scan.

Figure 4. MR volumetric studies of segmented SPGR. Post-processing of the images enables quantification of the volume of grey matter. (A) Baseline scan and (B) follow-up scan.
As one of Europe’s premier healthcare facilities, Karolinska University Hospital (Stockholm, Sweden) has a rich history in the development of clinical innovations and advancements in medicine. In close collaboration with industry, Karolinska’s clinicians and researchers work together to identify clinical needs, pinpoint areas for innovation and develop the best possible solution—all with a patient-centric approach.

First European installation of SIGNA Premier at the new Karolinska
In fact, the new Karolinska University Hospital opening in 2018 will provide highly-specialized care in a patient-focused setting that merges clinical practice, research and education. It will replace the existing hospital that was built in the 1930s.

According to Lucas Lönn, MD, neuroradiologist, the concept for the new hospital was to create a smaller-sized facility packed with high-tech equipment that would enable clinicians to deliver advanced care to more patients. For example, once all equipment is installed, the hospital will have 16 MR scanners across numerous care areas. Patient care will revolve around clinical specialties, for example, neurology, with the understanding that patients today can live with a disease for a long period of time—in some cases decades. This approach represents a new era in Stockholm’s healthcare system.

Lars Blomberg, RT(R)(MR), radiographer and MR super user at Karolinska, adds that a key benefit of the new hospital is that the services needed for a particular specialty are all geographically close.

“For patient treatment, everything was kept in close proximity. The neuro intensive care unit is right next to where the neuro MR scanners are sited. We don’t have to transport the patient far within the hospital.”

In the neuro department of the new hospital, there are five MR labs, two CT labs and three angiography suites. Although the department is separated on two floors, it was designed so that all emergency or urgent care patients could be assessed and treated on the first floor while ambulatory or outpatients could be evaluated on the second floor.

Of the five MR scanners, three are SIGNA™ Premier, the most advanced 3.0T, 70 cm bore MR system developed by GE Healthcare. The other two are Optima™ MR450w 1.5T 70 cm wide bore systems.

An investment in the future
From the start, the neuroradiology team at Karolinska University Hospital knew they wanted to implement advanced 3.0T MR systems at the new hospital. As a multi-vendor facility, the team did a thorough evaluation of all available 3.0T MR systems. It became clear that SIGNA™ Premier was the best possible choice for the facility and its patients.

The department is very hands-on with its MR scanner, including developing coding for advanced sequences. Therefore, Dr. Lönn says the team wanted the fastest gradients available today to perform advanced imaging techniques. SIGNA™ Premier delivered.

"Initially, we had planned for three 1.5T and two 3.0T systems for the new hospital,” Dr. Lönn says. “We decided to change that around because we believe that most, if not all, of the advanced neuro MR techniques that will become available in the future will be in 3.0T. Now that we’ve scanned with the SIGNA™ Premier, I know we made a very good decision to select it.”

Dr. Lönn has no doubt that with SIGNA™ Premier, the team will be able to push the boundaries in terms of clinical care and research.

“On the SIGNA™ Premier, we instantly got reasonable image quality,” Dr. Lönn says. “It is a brand new system, so I initially expected to have issues. But, we were up and running from day one, with more or less no trouble optimizing the system. I was very impressed with that; it was like buying a new car, putting in the keys and it just runs.”
Simply elegant
Patrik Vikström, RT(R)(MR), radiographer and MR super user at Karolinska, is also impressed after the first four weeks of scanning. “So far we’ve mainly been optimizing our existing standard sequences but it will be very exciting to see what we can do with all new techniques.”

However, Vikström does appreciate the capabilities to perform reformats and MIPs on the same page in the user interface. He also finds the drag-and-drop feature an efficient tool that helps him navigate through the complexity of MR scanning.

Blomberg found the console in the examination room, as well as the different functions, were easy to learn and understand. While he is familiar with the interface, as it is similar to prior GE systems, he believes it will be easy to teach new radiographers how to use the new scanner.

Both Blomberg and Vikström have been equally impressed by GE Healthcare’s 48-channel Head Coil, designed to fit 99.99% of the patient population while preserving or increasing SNR.

“With the 48-channel Head Coil, patient comfort is very high,” Vikström says. “There is a lot of room in the coil so it doesn’t feel so tight or restrictive to the patient.”

It is easier to position the patient and the Comfort Tilt that has been added to the coil serves almost like a pillow for the patient, Blomberg adds. In fact, he had a patient who had been scanned on an older system with a different head coil. “The patient commented that the comfort was much better on the new SIGNA™ Premier system with the wider table and more spacious head coil.”

The wider patient table really contributes to patient comfort and easier patient positioning for the radiographers, Vikström adds. Other features that can help the technologists more efficiently scan patients include the ease of placing landmarks, table speed, auto coil selection and additional choices for matrix.

Pushing the limits of neuro MR imaging
From the beginning, the team’s goal was to obtain the same image quality as the Discovery™ MR750w, and then work step-by-step to optimize scanning in terms of exam time. While the team also worked to enhance image quality, Dr. Lönn says that capability is second to speed.

“Our main objective was to optimize the scan time. We are going to scan thousands of patients over the year, and we want to get as many patients as possible in the scanners,” Dr. Lönn says. “At the same time, we must have good image quality.”

After one month using SIGNA™ Premier, the team has already achieved significant success. Overall, scan times are down 30% for most of the neuro sequences they’ve used. Dr. Lönn believes they can scan even faster without impacting diagnosis. And, the ability to obtain higher resolution scans is an added bonus.

“For select cases, we can increase image quality by spending more time scanning,” he adds. “That’s a nice option to have.”

One sequence that has really impressed the team is the Double Inversion Recovery (DIR) sequence with HyperSense. In
In Practice

the same scan times, Dr. Lönn noted increased differential of pathology with a Sagittal T2 Cube DIR compared to a Sagittal T2 Cube FLAIR. In one case, the DIR sequence depicted cortical lesions in a multiple sclerosis patient that could not be seen with any other sequence (Figure 1).

“DIR could be a very important tool in MS, and I expect we’ll incorporate it into regular MS patient follow-up exams,” he explains. Dr. Lönn is also impressed with the MultiShot Diffusion EPI (MUSE) diffusion of the brain after only three days of optimizing the sequence. “With MUSE and its distortion reduction, we can see structures in the brain like never before,” he says. “Compared to the old diffusion, we are getting really good quality because MUSE allows higher spatial resolution with reduced EPI-based distortions. That is a really big step in the right direction, and it’s now our new standard diffusion sequence.”

In one case, he could clearly see the resected pituitary gland and inner ear (Figure 2).

For evaluating metastatic lesions in the brain, Karolinska has relied on BRAVO for 3D T1 imaging. However, Dr. Lönn is quite satisfied with the results of MPRAGE compared to BRAVO (Figure 3).

"With MPRAGE we can get better contrast compared to using BRAVO," he explains. "In select cases, such as..."
Perhaps most impressive was the 3D Time-of-Flight (TOF) with HyperSense. Vikström pushed the sequence to the maximum HyperSense factor of 2.5 and was able to achieve good image quality. Then, he scaled back just one-tenth, to a HyperSense factor of 2.4. Dr. Lönn was not only very satisfied with the image quality of the high resolution (916 x 916) 3D TOF acquired in 7:35 minutes, he was thrilled at the imaging options presented to him.

“Peripheral vessels don’t get that clear on MR,” Dr. Lönn says. He found it comparable to a CT scan and even called the CT neuroradiologist to look at the images. “I would perform this scan on any patient who can’t have a CT scan or contrast. With HyperSense, we can perform the MR sequence faster with the same quality or keep the scan time and get higher spatial resolution.” (See Figure 4.)

Overall, the team is extremely pleased with the progress made in optimizing both new and old sequences on SIGNA™ Premier. “It is amazing that we could so quickly optimize the images to our standards on a new system,” Vikström says.

“It is not hard to find stunning images from the first few weeks of scanning on the SIGNA™ Premier,” adds Dr. Lönn.

Figure 4. 3D TOF with HyperSense factor of 2.5 at high resolution (916 x 916) with a total scan time of 7:35 min. According to Dr. Lönn, the image quality is comparable to a CT scan.

epilepsy or cortical dysplasia where we are looking for subtle changes in the grey-white matter junction, this is very nice to have.”

The team has also examined the benefits of HyperSense. Vikström utilized 3D T2 FLAIR with HyperSense using a factor of 1.3 and was able to achieve a 40% reduction in scan time with comparable image quality.

High-resolution T2 HyperCube with HyperSense was compared to the FIESTA sequence, which is routinely used for imaging of the cranial nerves. After optimizing the sequence, Dr. Lönn found the T2 HyperCube with HyperSense delivered better quality imaging than FIESTA with the added benefit of being able to perform it post-contrast with similar quality.

“If we immediately administer contrast, it is often a problem with FIESTA,” Dr. Lönn explains. “We now have a very useful tool that will also help us speed up the exam.” For example, by using T2 HyperCube with HyperSense, the contrast can be administered to the patient outside the scan room. That can lead to more efficient patient preparation that also frees up the scanner time.

“Most centers would agree that patient preparation time sometimes takes longer than the actual scan time,” Dr. Lönn adds.

‡ The high-resolution achieved was not possible prior to implementing HyperSense.
‡‡ Not all applications come standard on all systems. Please contact your GE Representative for the most current information.
Imaging the brachial plexus in a 10-minute 3D MR scan

By Ngo Van Doan, MD, MMed, Vice Head of the Diagnostic Imaging Department, Vinmec Times City International Hospital, Hanoi, Vietnam

**Introduction**

MR imaging of the brachial plexus often involves several clinical challenges. Complex anatomy, comprised of roots, trunks, divisions and chords can be challenging, particularly if the patient has an abnormal variant of the nerve root. Further, investigating injuries or lesions in the brachial plexus with traditional 2D imaging can be further complicated if it resides in the trunk, divisions or chords, although this is not a common occurrence.

At our facility, HyperSense and HyperCube have been implemented on the SIGNA™ Pioneer. A key benefit of 3D imaging using HyperCube is the acquisition of high-resolution data that facilitates the identification of normal anatomy as well as lesion location and classification.

In cases involving a vehicular accident (motorbike or car), it is not uncommon for the patient to sustain a rupture or avulsion—a pseudo-meningocele of the spinal cord. In these cases, a rapid yet comprehensive MR exam is preferred for diagnosis.

**Patient history**

A 22-year-old involved in a motorbike accident one month prior presented with numbness in the right arm. The patient was previously diagnosed with an injury to the brachial plexus. MR imaging was performed to confirm prior diagnosis and further evaluate the injury.

**MR findings**

2. C7 nerve root: partial rupture, decreased post-ganglionic nerve’s diameter without nerve stretching.
3. C8 nerve root: nerve root avulsion, T2 hyper-signal post-traumatic pseudo-meningocele, edema with increased diameter of the post-ganglionic nerve.
4. T1 nerve root: no abnormality noticed.

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**SIGNA™ Pioneer**

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Figure 1. Coronal HyperCube STIR sequence in a 4:23 min scan time with 1 mm slice thickness and a 40 x 40 cm FOV. (A) Right brachial plexus oblique reformat and (B) left brachial plexus oblique reformat.

Figure 2. Axial T2w HyperCube sequence in a 5:42 min scan time with 0.5 mm slice thickness and a 18 x 14 cm FOV. (A) Coronal reformat and (B-D) Axial oblique reformats (location of reformat indicated by dotted color lines).
Using volume rendering and maximum intensity projections on the Advantage Workstation, we can more easily visualize the lesion and its exact position. HyperCube provides us with better tissue contrast and spatial resolution compared to conventional 2D imaging. Additionally, a brachial plexus MR examination can be completed in a total scan time of 10 minutes by using two high-resolution HyperCube sequences with a HyperSense acceleration factor of 1.3 with the STIR sequence and a 1.5 factor with the T2-weighted sequence. At Vinmec, we are routinely using these sequences due to the advantages of reduced scan time and high-resolution imaging.

**Discussion**

By utilizing 3D HyperCube with STIR, it is easy to visualize the brachial plexus post-ganglionic branches with background flow suppression and nerve contrast optimization. The C8 branch is difficult to view on conventional MR imaging techniques but it can be clearly seen using this new sequence.

The pre-ganglionic lesion is well appreciated on the high-resolution T2-weighted HyperCube sequence. The nerve roots can be clearly visualized and evaluated in scanning and reformat planes without losing spatial detail. The dark nerve roots are well delineated in contrast to the uniformly bright cerebrospinal fluid throughout the volume of scan coverage.

The high spatial resolution and good image contrast are helpful to recognize the normal and variant nerve structures and the lesion or injury.

Figure 3. Axial T2w HyperCube sequence in a 5:42 min scan time with 0.5 mm slice thickness and an 18 x 14 cm FOV. (A) Coronal reformat and (B-C) Axial oblique reformat (location of reformat indicated by dotted color lines).
Diagnosing focal myocardial hypertrophy in a 15-minute cardiac MR exam using ViosWorks

By Vincent Martinez de Vega, MD, Head of Diagnostic Imaging Service, University Hospital Quiron Salud Madrid, Spain

Optima™ MR450w GEM

PARAMETERS

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**Introduction**

A comprehensive cardiac MR (CMR) study routinely requires inclusion of cardiac volume measurements and global/segment cardiac function. However, this type of patient exam can be very lengthy to acquire the necessary information—often 60 to 90 minutes requiring 20 to more than 50 breath-holds. In some cases, this can also lead to suboptimal imaging results as many patients undergoing CMR may be acutely ill and unable to remain still and hold their breath throughout the study.

One aspect of a CMR exam that consumes the most time is obtaining white blood images to assess morphology and function using 2D FIESTA sequences acquired in short axis. Replacing this scan with a short axis 3D acquisition acquired in one or two breath-holds is very important as it can save a significant amount of time. For example, scan time of a typical 2D Cine acquisition is 8-10 minutes. In this particular patient case presented below, the 3D Cine scan time was 39 seconds to acquire two slabs, representing a scan time reduction of approximately 92%.

Post-processing of CMR imaging data is another time-intensive process. However, by using the cloud-based, deep learning segmentation of ViosWorks, powered by Arterys™, we can significantly shorten the time needed to review and correct the segmentation. Typically, viewing and correction time of 3D Cine using ViosWorks is less than one minute. In the case presented, the total time spent viewing and correcting the automatic segmentation was 2:15 min due to the complexity of the hypertrophy cardiomyopathy requiring a greater degree of manual correction.
**Patient history**

A 35-year-old patient presented with a complaint of palpitations. ECG indicated arrhythmias and a prior echocardiography exam demonstrated a focal hypertrophic cardiomyopathy affecting the anteroseptal basal region with left ventricular outflow tract obstruction. Anterior displacement of the mitral apparatus and systolic anterior motion (SAM) of the mitral anterior leaflet was also noted.

A CMR exam was indicated for the evaluation of myocardial hypertrophy and areas of fibrosis (using late enhancement).

**Protocols used**

A fast CMR exam was performed in less than 15 minutes with ViosWorks. The exam included:

- Real-time planning
- 3D Cine short axis
- 4D Flow after intravenous contrast injection
- Late enhancement (single shot)

**MR findings**

The 3D Cine short axis sequence, in a scan time of 39 seconds, provided a left ventricular ejection fraction of 75% and a left ventricular stroke volume of 74.75 ml/beat.

With an acquisition time of 6:30 minutes, the 4D Flow sequence provided a gradient pressure of 29 mmHg with eccentric jet flow in the tubular ascending aorta with turbulent flow. Diameter of the aorta was measured at 31 mm.

The single-shot late enhancement sequence consisted of a short axis acquired in 34 seconds and a long axis acquired in 34 seconds. An intramural enhancement was detected inside the hypertrophic myocardium consistent with the presence of fibrosis.

**Acquisition and processing time**

Figure 1. ViosWorks can significantly shorten the time needed to review and correct the segmentation in CMR exams.

Figure 2. A comparison of (1) 2D Cine scan time + time needed to review and correct ViosWorks segmentation with (2) 3D Cine acquisition time + time needed to review and correct ViosWorks segmentation. 3D Cine with deep learning segmentation leads to shorter examination and analysis time.

**Acquisition and processing time**

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Ventricular function analysis, scan time and processing time: 2:10 minutes.
Figure 3. (A) Flow acceleration in the left ventricular outflow tract due to myocardial hypertrophy. (B, C) Eccentric jet flow in the tubular ascending aorta with turbulent flow. Diameter of the aorta: 31 mm.

Figure 4. Gradient Pressure: 29 mmHg.
Discussion
The main drawback of CMR is the long acquisition and interpretation times. Thus, a main objective is to reduce scanning and post-processing time to enhance the diagnostic quality of CMR and increase clinical productivity. Newer, fast sequences such as 3D Cine and late enhancement single shot significantly reduce scan time. 4D Flow provides comprehensive information on a patient’s vascular and valvular flow with a reasonable acquisition time. This sequence has several advantages with respect to the 2D phased-contrast sequences:
- Flow volume measurements with 4D Flow have good internal consistency
- QP/QS is obtained in the same dataset (same cardiac cycle)
- Retrospective placement of analysis planes at any location
- Valve tracking may improve assessment of flow in the heart valves
- Free breathing
- Easy to prescribe

The post-processing capabilities of ViosWorks using deep learning algorithms delivers quantitative data and structured reporting capabilities and also reduces time and increases a radiologist’s productivity.
3D ASL to distinguish tumor recurrence from pseudo progression

By Dr. Khaled Sherlala MBCh, MRCP(UK) FRCR(UK), Consultant Neuroradiologist, University Hospital of Coventry and Warwickshire, Coventry, UK

Glioblastoma, also referred to as glioblastoma multiforme, is an aggressive and usually highly-malignant tumor that forms from cells called astrocytes that support nerve cells. Surgery is often the first course of treatment to remove as much of the tumor as possible. Because glioblastoma grows into the normal brain tissue, complete removal is often not possible.

Serial MR imaging post-surgery is typically employed to guide disease management decisions. Tumor resection followed by chemoradiotherapy with temozolomide (TMZ) and adjuvant TMZ is a standard therapy for glioblastoma patients. However, one challenge of post-treatment surveillance is determining whether a suspicious lesion is from post-treatment radiation effects, such as pseudo progression, tumor recurrence or radiation necrosis. Where conventional MR often will not provide the information needed to determine the type of lesion, perfusion and diffusion-weighted imaging have been shown to be useful. In our facility, we utilize 3D ASL for neuro perfusion imaging of glioblastoma patients.

**Patient history**
A 53-year-old woman presented in September 2016 with seizures and was referred for an MR exam. Results showed an enhancing lesion in the left frontal lobe thought to be a primary malignant tumor. She underwent debulking surgery and the histology confirmed glioblastoma. She also underwent chemotherapy and radiotherapy post-surgery.

In May 2017, her recurrent seizures returned. MR imaging depicted an approximate 2.8 cm enhancing lesion at the bed of the excised tumor, raising the question of whether this is a tumor recurrence or pseudo progression.

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**Optima™ MR450w 1.5T**

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Figure 1. (A) Axial T2 PROPELLER, (B) Axial T1 pre-contrast, (C) Axial 3D ASL CBF map, (D) Axial T1 post-contrast and (E) 3D ASL CBF images. (C, E) 3D ASL and (D) T1 post-contrast images clearly demonstrate an area of very high blood flow, indicating that the glioblastoma had returned.
MR findings
3D ASL clearly demonstrated that there is increased perfusion (Figure 1), which is seen with true progression (tumor recurrence). The patient underwent a second surgery and histology confirmed glioblastoma.

The patient had an MR exam with 3D ASL after the second surgery which showed post-operative changes. The area of high perfusion found in the pre-surgery MR exam, however, is no longer apparent, indicating excision of the tumor (Figure 2).

Discussion
This case illustrates the usefulness of 3D ASL in helping neuroradiologists distinguish between pseudo progression and true progression/tumor recurrence. It is also very helpful in showing the extent of the tumor excision which can be very difficult to discern immediately in the post-operative period due to the presence of blood product, which makes it very difficult to distinguish between true enhancement or methemoglobin in the T1 sequence.

Today at our facility, we routinely use 3D ASL with all our neuro-oncology patients and it has replaced our dynamic contrast perfusion MR. 3D ASL is less cumbersome to use, particularly for our junior radiographers, and it takes only four to five minutes for the sequence. Post-processing on the Advantage Workstation (AW) takes less than one minute to perform.

Further, 3D ASL can be used on both 1.5T and 3.0T MR systems with no significant difference in image quality, as demonstrated in this case performed on the Optima™ MR450w 1.5T. In particular, our clinicians appreciate the color maps demonstrating highly perfused regions of the tumor.
T2-weighted 3D Cube for detection of spinal neuroma

By Sebastien Touraine, MD, CSE Medical Imaging, Paris, France

Neuromas are benign tumors that develop in the protective sheathing surrounding the nerve cells, typically at the site of a traumatic injury or even surgery. Spinal neuromas often press on the spinal cord and nerves, causing pain, numbness and weakness.

Detecting a spinal neuroma requires high spatial and contrast resolution in T1- and T2-weighted MR imaging. Diagnosis may be challenging due to the presence of herniated discs or post-operative scar tissue, especially if the neuroma is located in the foraminal space.

Often, contrast-enhanced FatSat T1-weighted images are helpful in the diagnosis of spinal neuromas. 3D imaging can also be useful for describing the precise location of the neuroma and in assessing volume and calculating measurements for patient follow-up exams.

Patient history
A 40-year-old female was referred for follow-up of a known neuroma within the filum terminale. Patient had prior MR exams in 2014 and 2015.

MR technique
A 15-minute total exam time including patient positioning consisting of the following sequences:
- Sagittal T2 with DST; scan time of 2:46 minutes
- Sagittal T1; scan time of 2:06 minutes
- Axial T2 3D Cube; scan time of 3:01 minutes
- Axial T1 FatSat post-contrast (15 ml Dotarem™); scan time of 3:41 minutes.

MR findings
Patient has a neuroma within the filum terminale at the level of the L2 vertebrae with dimensions of 21 x 8.5 x 8.1 mm. It appears insulated. There is no spinal pachymeningitis cord pathological contrast enhancement and there is no spinal leptomeningeal cord pathological contrast enhancement.
Lightly degenerative cracking aspect of the L5-S1 disk with a discrete edema. No hernia and no secondary narrowing of the dural sac. There is no indication of spinal fracture, spinal canal stenosis or a pathology within the spinal marrow. The spinal cord and the dural sac have normal topography and the medullary conus has a normal signal.

Conclusion: Stability of the filum terminale neuroma—with a main line of 21 mm—at the level of the L2 vertebrae.

Discussion
The diagnosis of neuroma is an important element to explain the patient’s radicular pain and may require specific surgical treatment or follow-up. The high image quality of T2-weighted 3D Cube images in assessing the lesion is crucial, especially at longitudinal follow-up, as it allows us to measure the main axis in the same plane as the prior examinations.
Fueling the future of MR

SIGNA™Works, GE Healthcare’s platform that redefines productivity across the breadth of core imaging techniques, is now available on SIGNA™ Voyager. The SIGNA™Works standard applications portfolio is an extensive set of high-quality and efficient imaging capabilities that enables clinicians to achieve desired outcomes across their entire practice area.

The SIGNA™ Voyager comes pre-loaded with SIGNA™Works standard applications as a fully integrated solution. It’s value-added technology that is upgradeable and customizable, giving healthcare providers the flexibility to add applications as needed. SIGNA™Works takes full advantage of Total Digital Imaging (TDI), further advancing diagnostics and quickening throughput, while simultaneously helping improve patient outcomes and ROI.

With this new offering, Cube scans shown in this article will be able to take advantage of GE’s compressed sensing technique, HyperSense, to increase productivity and throughput. Additionally, with the novel uses of HyperCube and Flexible No Phase Wrap, scan times can be reduced further to improve the patient experience.

‡SIGNA™Works on the SIGNA™ Voyager is not available in all regions.
Advanced and quantitative MR imaging in MSK

The Hospital for Special Surgery (HSS), New York, NY, is nationally ranked as the number one hospital for orthopedics and the number three hospital for rheumatology by U.S. News & World Report (2017-18). In addition to being the nation’s oldest orthopedic hospital, HSS also performs more hip surgeries and knee replacement surgeries than any other hospital in the US.

HSS and GE continue to collaborate on research in MR musculoskeletal imaging. The following articles describe some of the MR-specific clinical research underway at HSS that is being supported by GE.

The authors gratefully acknowledge the assistance of the following GE scientists for their contributions to this work: Michael Carl, PhD; Shiv Kaushik, PhD; Jaemin Shin, PhD; Maggie Fung, PhD; and Rob Peters, PhD.

With a “bench-to-bedside” team of doctors and scientists, HSS swiftly translates scientific breakthroughs into clinical treatments. The hospital’s radiology department, led by Hollis Potter, MD, Chairman, continually demonstrates its leadership in orthopedic and MSK imaging. HSS radiologists have developed new protocols for diagnostic imaging of bones, tendons, ligaments and other soft tissues. HSS and Dr. Potter worked closely with GE Healthcare in the development of MAVRIC SL, an acquisition and reconstruction technique for imaging soft tissue and bone near MR Conditional metallic devices.
Isotopic MAVRIC SL‡ delivers thinner slices, reduced scan times

By Matthew Koff, PhD, Associate Scientist, and Hollis Potter, MD, Chairman, Department of Radiology and Imaging, Hospital for Special Surgery, New York, NY

The development and commercialization of MAVRIC SL has led to a safe and effective means to evaluate soft tissues and osseous structures around MR Conditional implants and instrumentation using MR imaging.¹ At the Hospital for Special Surgery (HSS), we have an active adult reconstruction and joint replacement program, including revision arthroplasty for patients who have a failing total joint replacement. Our surgeons rely on the data provided by MR imaging for post-operative monitoring of patients with pain, identification of failing total joint replacements and planning of subsequent treatment.

MAVRIC SL was instrumental in enabling our clinicians to visualize adverse local tissue reactions (ALTRs) in patients with metal-on-metal total joint replacements or hip resurfacing replacements. ALTRs are commonly asymptomatic and a patient may have no pain and good joint function. ALTRs are frequently “clinically silent” and continue to develop within the patient and lead to destruction of soft tissues around the joint replacement. MAVRIC SL enables the identification and detection of the soft tissue area being affected by an ALTR and the ability to diagnose them early before they spread beyond the capsule into the surrounding soft tissue with attendant damage.

Figure 1. (A, C) MAVRIC SL, (B, D) Isotropic MAVRIC SL. Isotropic MAVRIC SL has better depiction of the (B) focal synovial reaction in the infero-medial joint recess (arrow) and (D) better display of synovial debris (arrow).
Currently, MAVRIC SL acquires 24 bins of off-resonance data to generate images. In small implants or instrumentation, or those with weaker metallic susceptibility such as metal-backed ceramic constructs, many of these bins may not contribute useful information to the final images and may cause elevated ghosting at the expense of increased scan time. We hypothesized that MAVRIC SL with an isotropic and reduced bin acquisition would enable clinicians to acquire thinner slices with a clinically feasible scan time and permit data reformatting in any plane.

At HSS, our standard protocol is to acquire the MAVRIC SL data in the Coronal plane with 3 to 4 mm thick slices. An additional exciting addition is isotropic MAVRIC SL, which enables us to achieve 1.3 mm isotropic voxels, potentially obviating the need to collect imaging data in the corresponding Sagittal and Axial planes.

Further, with the advent of more advanced MR systems and calibration scans, we determined that with the isotropic MAVRIC SL acquisition we could reduce the number of data bins from 24 to 12 when imaging a metal-on-metal implant, which is comparable to cutting the standard MAVRIC SL scan time by a factor of two. In patients with ceramic or plastic implants, the intelligent calibration scan has helped reduce the number of bins to as low as six or eight, further reducing scan time. Acquiring a reduced number of bins together with isotropic voxels allows us anatomic coverage of the entire total joint replacement in a clinically feasible scan time.

In our initial evaluation of the image quality of isotropic MAVRIC SL to MAVRIC SL, we noted comparable tissue contrast, but better overall signal-to-noise ratio and image quality. In some cases, we found better conspicuity of clinically relevant lesions, such as osteolysis and a fibrous interface at the bone-implant interface, as well as less blurring due to the thinner slices.

Further, isotropic MAVRIC SL may be most useful for the evaluation of implanted pins and screws where a clinical diagnosis may benefit from better through-plane resolution near smaller orthopedic hardware. The isotropic MAVRIC SL acquisition provides a non-invasive method to evaluate total joint replacement patients post-surgery or in cases of other implanted surgical hardware.

At ISMRM 2018, we are presenting the initial findings of a pilot cohort study in subjects with total hip replacements using isotropic MAVRIC SL.²

References

²Technology 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 U.S. FDA or any other global regulator for commercial availability.
Update on magnetic resonance neurography

By Darryl B. Sneag, MD, Radiologist, Hospital for Special Surgery, New York, NY

Dedicated MR imaging of peripheral nerves, or MR neurography (MRN), is challenging but simultaneously extremely rewarding from an imager’s perspective. It involves a focused approach, optimized to detect pathology in one or more nerves within any region of the body. As some peripheral nerves are very small (sub-millimeter in diameter) and course alongside blood vessels that can be difficult to distinguish from the nerve itself, MRN poses multiple technical challenges. Some imaging approaches that we have found successful are delineated below.

**Dixon fat separation imaging**

MRN can be divided into qualitative and quantitative imaging techniques. Qualitative techniques typically rely on heavily T2-weighted 2D and 3D sequences optimized for maximal contrast-to-noise ratio (CNR) of pathologic versus non-pathologic nerve as well as of the nerve relative to ‘background’ tissue (e.g., muscle and fat).

In the SIGNA™ Pulse of MR, Spring 2015 issue, we reported on the use of T2-weighted IDEAL demonstrating greater signal-to-noise ratio (SNR) and CNR to delineate nerve from adjacent muscle tissue and denervated muscle from normal muscle, as compared to a conventional STIR sequence. With improved water/fat separation reconstruction algorithms, the 2D, 2-point Dixon (Flex) technique can now provide the same robust fat separation as IDEAL. We have since integrated the Flex sequence into our routine protocol. As only two, rather than three, echo time acquisitions are obtained, there is a significant savings in scan time, enabling higher spatial resolution while maintaining adequate SNR.

**High-resolution surface coils**

We heavily rely on the 3.0T Flex Coil suite for upper and lower extremity peripheral nerve imaging. The coils involve 16-channel phased array designs and are available in different sizes to accommodate most body habitus. The 16-element design also accommodates different types of parallel imaging techniques to help maintain reasonable scan times with high spatial resolution.

One example in which the 16-channel coil is extremely helpful is imaging of the anterior interosseous nerve (AIN), the nerve innervating the flexor pollicis longus muscle (of the thumb) and flexor digitorum profundus muscles of the index finger and inconsistently the middle finger. AIN palsy results in the inability to perform routine daily activities, such as buttoning a shirt or picking up a coin. Recently, our group2,3 and others4 have been able to demonstrate focal intrinsic constrictions at the fascicular level—i.e., AIN fascicles of the median nerve proper—that can then be addressed with surgical microneurolysis (Figure 1). These constrictions are frequently < 1 mm in length and diameter. Precise lesion localization can lead the surgeon directly to the pathologic site, potentially saving many hours in the operating room.

One limitation of the Flex Coils is in imaging of long segment neuropathies, typically of the inflammatory kind (e.g., multifocal motor neuropathy), that may involve several nerves in multiple distributions extending from the shoulder to wrist or hip to ankle requiring numerous positional changes of the coil. The Flex Coils are also only flexible in the long axis dimension.
and prone to signal cancellation/interference when overlapped on themselves. The new AIR Technology Suite developed by GE aims to address these two deficiencies.

Brachial plexus imaging
Imaging of the brachial plexus is particularly challenging given inherent field inhomogeneities requiring robust fat suppression around the neck and motion artifact, particularly respiratory-induced. Acquiring oblique Sagittal planes, orthogonal to the longitudinal axis of the nerves, is critical to evaluate fascicular detail; this imaging plane, however, is particularly susceptible to aliasing from respiratory motion that if severe, can obscure the plexus (particularly the infraclavicular segments that course immediately adjacent to the lung) and render the exam uninterpretable. We recently completed a study of 25 volunteers and patients comparing respiratory-triggered to non-respiratory triggered oblique Sagittal T2-weighted Flex imaging of the plexus. In summary, we found more than a five-fold reduced ghosting artifact and four-fold improvement in image quality with respiratory triggering (Figure 2).5

Another challenge with brachial plexus imaging is acquiring sufficient SNR in the region of the infraclavicular plexus and terminal branches. Traditional coil arrangements have involved the neurovascular array, which provides adequate SNR in the lower neck region to delineate the extraforaminal roots and trunks, but falls short in providing adequate SNR to delineate the infraclavicular plexus and terminal branches. As such, we prefer the use of the small or medium Flex Coils secured over the neck/shoulder region, and find that this coil setup works for almost all patients.

Employing 3D imaging (Cube) in the brachial plexus region can be helpful to delineate pathology as it facilitates 1 mm³ isotropic acquisitions that can be readily post-processed without distortion into arbitrary planes and used to create curved multiplanar reformations. The Cube Flex sequence provides inherent increased SNR to the Cube STIR sequence, but anecdotally we have found the Cube STIR sequence to afford higher CNR of nerves in most instances. Both sequences have the additional benefit of a FOCUS option, which employs an outer volume suppression technique to suppress signal outside of the desired field-of-view,6 and provides scan time savings by avoiding the No Phase Wrap option.

Diffusion tractography using HyperBand
Diffusion MR tractography is an imaging tool that can depict the 3D spatial relationship between extrinsic and intrinsic masses, namely peripheral
nerve sheath tumors and adjacent nerves.\textsuperscript{7} Diffusion tensor imaging (DTI)-based tractography is the most widely used tractography method, but has fundamental limitations to resolve intravoxel, complex fiber bundle architecture at a millimeter-scale resolution due to oversimplification of the tensor model. This is exacerbated by partial volume effects, especially in the presence of pathology that may increase extracellular water content. Recently, many higher-order models, including the constrained spherical devolution (CSD) model, have been developed to address the limitation of the DTI framework.\textsuperscript{8,9} However, these models require High Angular Resolution Diffusion-weighted Imaging (HARDI) data and have not been regularly adopted in the clinical setting due to clinically impractical scan times. Most peripheral nerve diffusion MR-published protocols have employed higher in-plane resolution with thicker slices to maintain SNR, which introduces an orientation-dependent bias in diffusion measures.\textsuperscript{10,11} HyperBand, a multi-band acquisition in which multiple slices
are simultaneously excited with a multi-band RF excitation, significantly reduces acquisition time and facilitates the collection of isotropic or nearly-isotropic HARDI data in a clinically feasible acquisition time. We now routinely use the HyperBand sequence and then employ a post-processing denoising algorithm using generalized spherical deconvolution\(^\text{12}\) to generate more reliable tractography (Figure 3).

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References

Utility of ZTE MR for bone imaging

By Ryan Breighner, PhD, Computational Scientist, Hospital for Special Surgery, New York, NY

Zero Echo Time (ZTE) MR imaging is a promising technique for bone imaging. It has been variously utilized in neuro MR imaging (SilentScan), as well as in PET/MR imaging of the head for signal attenuation correction. Currently, it is being explored in morphological imaging of bone for musculoskeletal radiology applications at HSS.

Conventional MR sequences depict cortical bone tissue as signal void due to its short transverse (T2) relaxation time. ZTE is an extension of Ultra-short Echo Time (UTE) MR imaging, which has been used in the evaluation of meniscus, tendon and the calcified zone of hyaline cartilage.

Post-processed ZTE MR provides CT-like contrast for bone. In a study of shoulder morphology across various pathologies, quantitative measurements and subjective grading tasks were performed on concurrent CT and MR image sets—including an additional ZTE acquisition. We found that measurements and grades from ZTE MR imaging demonstrated strong intermodality agreement with CT. Further, when compared to conventional MR imaging, the ZTE MR provided superior visualization of osseous features in a majority of cases.

In addition, osseous features such as subchondral bone and osteophytes on the humeral head were rendered more visible in ZTE MR than conventional MR. Intraosseous ganglion cysts were readily apparent in ZTE MR, but not visible in CT.

Another recently published study evaluating the diagnostic accuracy of

Figure 1. Oblique MPR of (A) ZTE and (B) CT of the cervical spine from the same patient. The foramen of interest (circle) is seen as similarly stenosed in both modalities.
ZTE MR for the evaluation of cervical neural foraminal stenosis (CNFS) reported similar results. Proper assessment of CNFS is important to determine appropriate patient therapy—whether or not the patient should undergo surgical intervention. We found substantial agreement between the ZTE and CT grading of CNFS: 86% of ZTE MR-based CNFS grades were within one grade of the corresponding CT-based grades; inter- and intra-examiner agreements for ZTE MR and CT were similar, as well.7

Both studies demonstrate the potential for ZTE MR to be utilized in place of concurrent CT scans. Many patients with injuries to the joints (e.g., shoulder and knee) or spine undergo multiple cross-sectional examinations (MR and CT) to assess soft and osseous tissues. For these patients, it may be possible to eliminate the need for a CT exam by adding one or more five-minute ZTE MR sequences to the end of their MR exam. ZTE MR may be especially applicable to certain patient populations, such as pediatrics or those of childbearing age who are thought to be at greater risk arising from radiation exposure imparted by CT.

Additionally, we found that segmented ZTE MR images yielded better 3D models of bones than conventional MR, which may be useful in pre-surgical planning. The use of conventional MR with ZTE MR can enable the assessment of both soft tissue (ligaments, tendons, etc.) and bone in a single examination.

References

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Characterizing patellar tendinopathy with T2* values

By O. Kenechi Nwawka, MD, Radiologist, and Matthew Koff, PhD, Associate Scientist, Hospital for Special Surgery, New York, NY

As part of the NBA/GE Healthcare Orthopedics and Sports Medicine Collaboration, HSS was awarded a grant to study the longitudinal assessment of patellar tendinopathy in elite basketball players at the professional and collegiate levels using quantitative MR and ultrasound imaging. Patellar tendinopathy, commonly known as jumper’s knee, is a common cause of injury in basketball players that frequently leads to reduced performance.

Tendons typically appear as dark structures in a standard MR exam. Only when signal appears in the tendon is there a clear indication that biochemical composition changes are occurring.

Additionally, while standard MR sequences provide visualization of tendinosis and provide the treating clinician with information on whether a tear or stress reaction is present, the images cannot identify injury prior to symptoms, or predict how a player will respond to continued play or even treatment. Physicians treating professional basketball players would like to know if their patients can continue to play or if the player risks tearing a tendon without rest or treatment.

Ten collegiate basketball players underwent bilateral MR knee exams with multi-planar Fast-Spin-Echo (FSE) for morphologic evaluation and 3D Ultra-short Echo Time (UTE) for T2* values at the beginning and near the end of their season. The study endpoint is to determine if UTE MR imaging can classify the degree of tendon degeneration and provide a prognostic biomarker of tendon health. By looking at T2* values within the patellar tendon, we hope to gain insight into how the tendon is organized and how this fibrous connective tissue changes across the athletes. We hypothesized that increased T2* values at the end of the season would suggest degeneration of the tendon and that the associated T2* mapping would provide us information regarding changes in biochemical composition before it can be visualized in conventional MR imaging.

T2* values within the tendon may be separated into different “pools.” Pools of short T2* values are associated with more restricted (bound) water, and long T2* values are associated with more free water. The relative percentage of each pool within the tendon may indicate the overall health of the tendon.

The preliminary results suggest that T2* values are higher in the player’s dominant jumping knee. We have noted some correlation of these T2* values to injuries visualized in conventional, morphologic MR imaging, with greater degeneration present at post season, indicating a potential to predict degeneration based on T2* values. The results also suggest that the patellar tendons in the dominant and non-dominant limbs may experience and adapt differently over a basketball season.

Editor’s note: preliminary results of the study, Longitudinal Changes in Quantitative MRI and Ultrasound Metrics of Patellar Tendon are Associated with Tendon Degeneration and Leg Dominance within of Collegiate Basketball Players over One Season of Play, by Erin C. Argentieri, Matthew F. Koff, Bin Lin, Parina H. Shah, Hollis G. Potter, and O. Kenechi Nwawka, was presented at ISMRM 2018.

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Figure 1. Example of changes in T2* short and morphology within one subject from pre- to post-season time points.
Exploring MR powered by

Applied Intelligence

By Victor Justo, 3.0T Marketing Director, Global MR-XLP, GE Healthcare

When we look at MR imaging today, we see technologists and radiologists who are under more pressure than ever to scan and read results efficiently and accurately.

What’s more, every exam generates vast amounts of data to process and analyze. As radiologists are pressed for time, they can’t make sense of all the raw data being generated. It’s no wonder many departments are dealing with high levels of radiologist fatigue.

Our customers are demanding streamlined workflows as well as advanced imaging visualization and reporting tools that can help improve clinical outcomes and diagnostic confidence, while working more efficiently. In this context, intelligent scanners, applications and services must provide new capabilities. Quantitative data aggregation, analytics and collaboration will change the landscape of what is achievable, improving timeliness of results, accuracy and patient safety.

Our Applied Intelligence philosophy

GE Healthcare provides a comprehensive set of technologies that deliver on the promise of personalized care for all types of patients, regardless of their physiology.

We are combining software applications with best-in-class medical devices and services to deliver powerful insights through data and analytics for near real-time results. At the heart of our approach is Applied Intelligence—the artificial intelligence and analytics brain that powers GE’s leading applications, devices and services enabled by our Health Cloud.

Applied Intelligence will become the digital thread that flows between the machines and software to unlock an organization’s full potential with insights that help administrators and clinical staff deliver better patient outcomes more efficiently. It will allow customers to automate what used to be manual so they can concentrate on what matters most: the patients.

MR is a critical component of this shift toward precision health. We’re using Applied Intelligence to personalize the MR scan for each patient, enabling the technologist to capture information faster and more precisely. Ultimately, this will help us deliver on the promise of personalized care for all.

We can find Applied Intelligence in three areas:

Intelligent applications: By leveraging machine learning and deep learning algorithms, software solutions and applications, healthcare providers can make better decisions faster. We are working towards augmenting clinical and operational staff decision-making by providing actionable insights.

Intelligent scanners: We are aiming to make our devices “intelligent” with the goal of reducing rescans and non-diagnostic studies, and improving patient throughput. GE is working towards devices that are more integrated, aware, intuitive and predictive—with the ability to automate and self-drive.
Intelligent services: We are moving toward connected, proactive and predictive services coupled with advisory services to help reduce downtime and maximize customers’ return on assets.

Partnerships as an accelerator
Our journey is well underway in offering digital solutions across devices, applications and services in a secure, connected digital ecosystem to help deliver better patient outcomes more efficiently.

We’re developing powerful new algorithms in partnership with leading healthcare institutions. Simultaneously, we are collaborating with established technology companies and innovative tech startups. An example of intelligent applications is ViosWorks, powered by Arterys. It uses deep learning, an advanced subset of artificial intelligence, to automatically perform contouring and segmentation of the left and right heart ventricles. Normally, full ventricular segmentation can take up to 25 minutes, or even longer for less experienced sites or more complex anatomies. With the cloud-based deep learning, segmentation is pre-processed, providing physicians instant segmentation and ventricular volumes upon opening a study. Deep learning is also used to automatically identify landmarks (valves and apex) in 4D Flow images, allowing the physician to obtain all the standard cardiac views instantly. By replacing manual, repetitive processes throughout the cardiac MR analysis, ViosWorks saves significant time in the clinician’s workflow.

There are numerous potential applications of artificial intelligence in the development of intelligent scanners. Imagine an MR system where the technologist does not have to worry about manually placing slices before an acquisition. Instead, an algorithm would rapidly identify anatomical landmarks and allow an automated, consistent and reliable patient-specific graphic prescription for all types of exams.

Similarly, algorithms could potentially assess the image quality of an exam, identifying series that need to be repeated and automatically prescribing the appropriate artifact-tolerant protocol to prevent specific failures.

Another great example of Applied Intelligence is our MR Excellence Program. We have combined analytics with MR technology to increase...
productivity and quality in imaging. The program started by defining several key performance indicators that would give insight into productivity and quality of care. We have built an IT-based solution that brings together machine data from the MR system during the scan, image data from the PACS and patient data from the RIS. It then aggregates this data and displays it in a dashboard, where management can analyze workflows, machine utilization, protocols and referral patterns to draw conclusions about productivity and workflow.

With Applied Intelligence, we will be able to personalize the MR experience for the tech and patient, simplifying procedures and reducing variability during complex exams. It will also help radiologists manage increasing volumes of data so they can easily extract the information they need to make a confident diagnosis.

Fundamentally, our strategy is to use patient-adaptive technologies and Applied Intelligence to enable precision diagnostics to ensure that the right actions are taken at the right time for each and every patient.

Glossary of terms

**Applied Intelligence**: The analytics and artificial intelligence “brain” that powers GE Healthcare’s applications and devices. It extracts and interprets data across healthcare IT systems, devices and imaging equipment to provide actionable insights, helping enhance and augment clinical, financial and operational decision making.

**Descriptive analytics**: Insight into the past. Get data together and use visualization to get quick views on what has happened.

**Predictive analytics**: Understanding the future. When current and historical data are combined with rules and algorithms to determine the probable future outcome of an event or the likelihood of a situation occurring.

**Prescriptive analytics**: Advises on the future. Prescriptive analytics predicts what will happen and tells why it will happen. It provides recommendations regarding actions that take advantage of these predictions (e.g., artificial intelligence).

**Artificial intelligence (AI)**: AI is the ability of a machine to mimic human intelligence. In practice, it is a segment of computer science that involves designing computer applications to perform tasks that typically have required human intelligence such as visual perception, speech recognition and decision-making.

**Machine learning**: An application of AI that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves.

**Deep learning**: A subset of machine learning that has networks which are capable of learning unsupervised from data that is unstructured or unlabeled. Also known as Deep Neural Learning or Deep Neural Network.
Initial results of an ultra-high gradient strength coil in diffusion imaging

By Allen Song, PhD, Director of the Duke University Brain Imaging and Analysis Center and Professor of Radiology at Duke University, Durham, NC and Doug Kelley, 7.0T Product Manager, Global MR, GE Healthcare

Diffusion imaging provides information on water diffusion characteristics that reflect the surrounding microstructure, which can then be used to infer structural connections between different parts of the brain. However, these connection patterns can be extremely complex and difficult to interpret. What new technologies can make the picture clearer? Improvements in gradient coil design and construction could certainly have a big impact, and the initial results of GE Healthcare’s collaboration with Duke University Brain Imaging and Analysis Center have been quite promising.

Diffusion imaging really asks a simple question. How can we distinguish different regions of tissue based on whether water molecules in those regions are free to move? To do so, we apply diffusion-weighting gradients along a particular direction to reduce the signal from moving spins while leaving stationary spins alone. By changing the direction of the gradient pulses, we can characterize the water motion in different directions and determine where diffusion is free, where it is hindered and confined to a particular direction, and where it is restricted (largely unable to move in any direction). Based on a comprehensive assessment of the movement characteristics of water molecules, we can often infer the microstructure of the tissue.

Because of the complexity of the brain connectivity, we often strive for the highest resolution possible. However, diffusion imaging has an inherently low signal-to-noise ratio (SNR) due to the need to accommodate the diffusion-weighting gradients, which attenuate signal and also prolong TE, both reducing the SNR and making high-resolution imaging highly challenging. To alleviate this constraint, it is necessary to have the strongest possible gradient coil. Fortunately, GE is working to develop new design and manufacturing techniques that not only increase the gradient strength, but also effectively reduce excessive heating, heightened motion sensitivity and peripheral nerve stimulation.

Allen Song, PhD
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Specifically, by using water-cooled hollow conductors we are more than capable of extracting all the heat from an advanced, whole-brain diffusion tensor imaging protocol typical of a research setting. We also minimize the interactions with the magnet through a torque-balanced design, both to reduce vibration of the gradient coil and to ensure that the magnet remains stable during the sequence. Finally, the return paths of the conductors in the gradient coil are optimized to minimize peripheral nerve stimulation, which can often be a limiting factor for the high slew rate needed in advanced diffusion imaging.

In recent years at Duke, our work has focused on improving the spatial resolution of diffusion images using techniques such as MultiShot Diffusion EPI (MUSE). Through extensive collaboration between GE and Duke scientists, we were able to achieve high spatial resolution in the sub-millimeter range while also minimizing sensitivity to subject motion.

For example, GE provided an initial prototype of an all-hollow 60 cm gradient coil\(^\text{‡}\) to the Duke team in late 2016, using existing gradient amplifiers from the installed Discovery™ MR750 system. While not as powerful as the new gradient amplifiers from the SIGNA™ Premier, the combination still demonstrated some of the key benefits we were expecting—lower vibration, higher linearity and more signal due to shorter echo times (~30% reduction), providing the GE team with significant confidence.

In May 2018, GE will deliver the full SIGNA™ Premier system electronics with a new version of the gradient coil to the Duke team for use in their research. Also, in the GE development bay earlier this year, we already achieved peak strengths of 115 mT/m and slew rates of 225 T/m/s, among the highest performance ever demonstrated with a 60 cm patient bore. Initial human tests have shown great promise in reaching ultra-high spatial resolution. Figure 1 is an example demonstrating high image quality and detailed tractography throughout the brain at 1 mm\(^3\) isotropic resolution. Continuing our collaboration, we anticipate completing this installation quickly and demonstrating the benefits of this system for ultra-high, sub-millimeter resolution diffusion imaging over the course of 2018.

\(^\text{‡}\)Technology in development that represents ongoing research and development efforts. These technologies are not products and may never become products. Not for sale. Not CE marked. Not cleared, approved or authorized by any national regulatory authorities for commercial availability.
innovates wireless iPRES RF/shim coil with AIR Technology‡

A lightweight integrated RF/shim coil for simultaneous MR image acquisition, localized B₀ shimming and wireless data transmission

By Dean Darnell, PhD, Medical Instructor, and Trong-Kha Truong PhD, Associate Professor, Brain Imaging and Analysis Center (BIAC) at Duke University, Durham, NC
Currently, the general trend within MR hardware development is to decrease the complexity of the scanner and to improve patient comfort. For example, wireless power harvesting has been proposed to supply power to on-board RF coil electronics. Additionally, replacing the large spherical harmonic shim coils with an iPRES coil array for image acquisition and localized B₀ shimming may not only improve the shimming performance, but also widen the scanner bore for increased patient comfort. However, iPRES coil arrays require a network of wired connections and external DC power supplies in the machine room to be added to the system to perform B₀ shimming, which increases its complexity.

Traditionally, whole-body spherical harmonic shim coils have been used to improve the static magnetic field (B₀) homogeneity within the MR scanner bore for in vivo imaging.

To more effectively correct for localized B₀ inhomogeneities and image artifacts caused by susceptibility differences at air/tissue interfaces in the human body, our team at the Duke University Brain Imaging and Analysis Center (BIAC) designed a novel 32-channel integrated RF/shim head coil array, termed integrated parallel reception, excitation, and shimming (iPRES). The iPRES coil array allows both RF and DC currents to flow on the same coil elements, thereby enabling MR image acquisition and localized B₀ shimming with a single coil array. This iPRES coil array demonstrated a significant reduction in B₀ inhomogeneity (up to 83 percent), geometric distortions, and signal loss (up to 59 percent) in the human brain, which can benefit many applications such as diffusion tensor imaging and functional MRI (fMRI). Additionally, the iPRES coil design was improved by adding multiple DC loops and microelectromechanical system switches per RF coil element to further improve its shimming performance and cost-effectiveness for more challenging applications such as abdominal and breast imaging.
To address this issue, we have proposed a new wireless iPRES coil design, termed iPRES-W, that can perform MR image acquisition, localized B₀ shimming and wireless data transmission with a single coil by allowing a DC current and RF currents both at the Larmor frequency and in a wireless communication band to flow on the coil simultaneously. This innovative coil design uses a lightweight battery pack module mounted onto the coil to supply the DC current for shimming. The battery pack is wirelessly controlled by sending commands between the console room and the module via the iPRES-W coil. The requested DC current from the module then flows onto the coil to generate the magnetic field used for shimming. The iPRES-W coil design thus enables all the wired connections and external DC power supplies from the conventional iPRES coil design to be removed, reducing the system complexity.

Preliminary experiments were performed on a GE Healthcare Discovery™ MR750 3.0T scanner to demonstrate that wireless data transmission with an iPRES-W coil does not degrade image quality or the ability to perform B₀ shimming. Specifically, signal-to-noise ratio (SNR) maps acquired with an RF coil before (Figure 1A) and after (Figure 1B) iPRES-W integration demonstrated that the modifications performed to enable localized B₀ shimming and wireless data transmission did not affect the RF performance of the coil. In another experiment, localized B₀ inhomogeneities were introduced into a uniform phantom by applying a DC current into a perturbation loop.
Conventional RF coils are typically bulky, heavy and rigid, which affects patient comfort and adds constraints to the coil design. GE Healthcare recently introduced an evolution in MR coil technology with the AIR Technology Suite, which provides flexible, lightweight and high-density coil arrays that can conform to the shape of the human anatomy, thereby improving patient comfort.\textsuperscript{10} It also delivers clinical coverage with high SNR and optimized geometries for maximum use of parallel imaging.

Building upon these encouraging preliminary results, our team has further integrated the iPRES-W coil design with the AIR Technology Suite, yielding a single coil design: the iPRES-W utilizing the AIR Technology Coil that combines the advantages of these two complementary technologies, namely an improved $B_0$ homogeneity and a superior RF performance. Additionally, patient comfort is preserved in this new coil design because the modifications required to enable localized $B_0$ shimming and wireless data transmission do not add significant weight or wired connections to the scanner.
Proof-of-concept experiments were conducted with an iPRES-W utilizing the AIR Technology Coil to demonstrate that it could perform wirelessly controlled B₀ shimming.¹¹ As in the iPRES-W coil experiment, localized B₀ inhomogeneities were introduced into a water phantom, producing significant geometric distortions in an echo-planar image (EPI) (Figure 3B, orange arrows), which were then drastically reduced when shimming with this new coil (Figure 3C, green arrows).

Combining our highly innovative iPRES-W coil design with the AIR Technology Coil will enable simultaneous MR image acquisition, localized B₀ shimming and wireless data transmission with a single flexible and lightweight coil array, which we believe will be highly valuable for a wide range of MR applications.

We are grateful for the collaboration and guidance provided by Fraser Robb, PhD, and Robert Stormont from GE.

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³Compared to a new GE MR system – upfront cost includes equipment, construction required for the equipment install and potential mobile cost during downtime. Actual costs will vary depending upon your site’s specific circumstances.

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