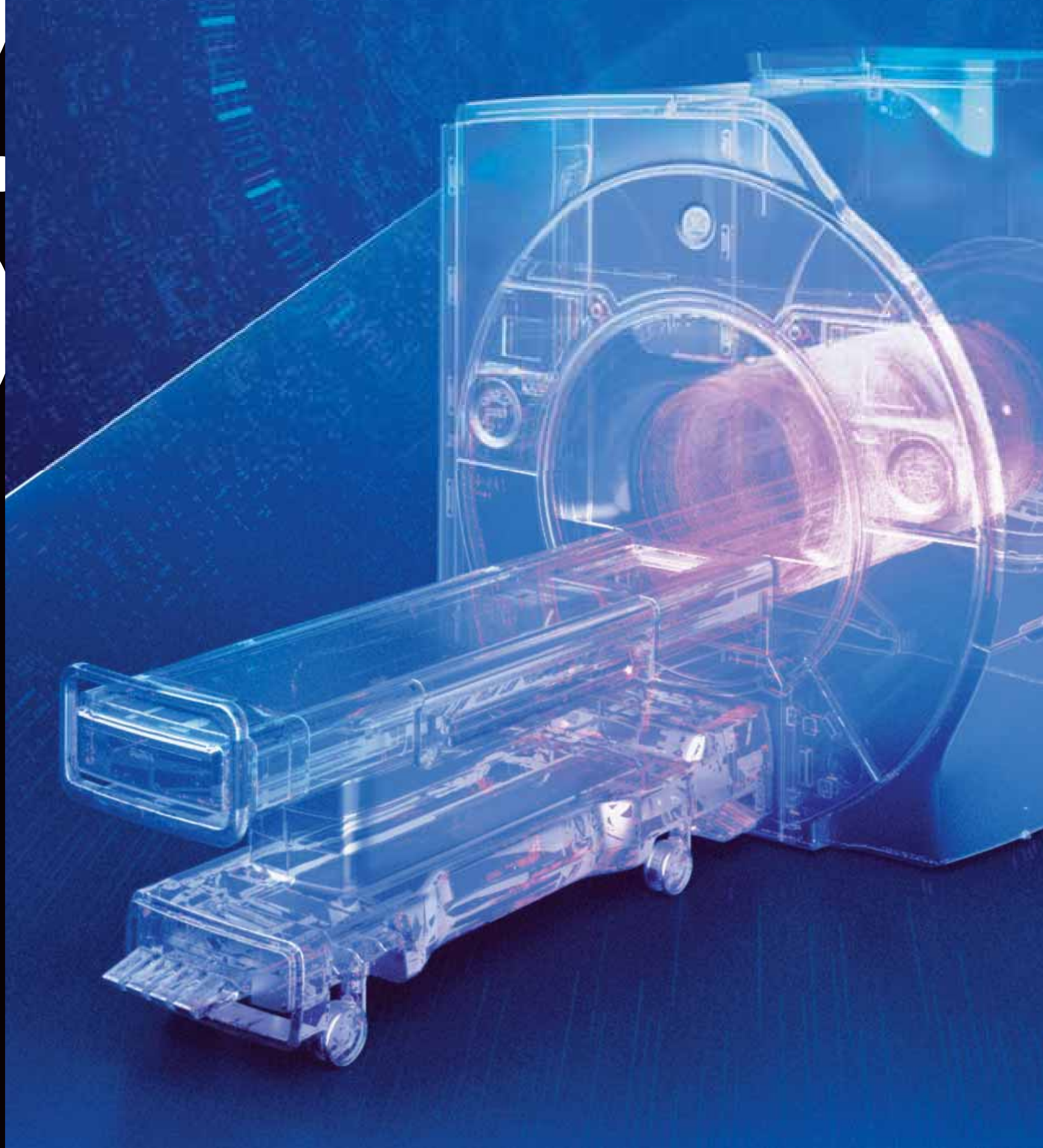
SIGNA™

ELEVATING RADIOLOGY WITH INTELLIGENT MR

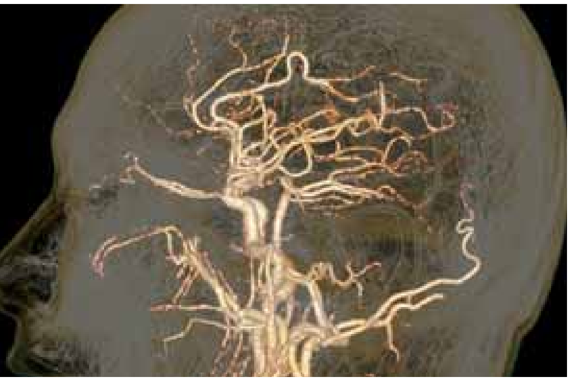


Pulse of MR

Autumn 2018

RSNA Edition

Volume Twenty-Five



Outside the Bore

Issue Spotlight

In Practice

Publications Team:

Stephanie Broyhill
Editor-in-Chief
Marketing Communications Leader, Global MR

Kerry Adapathya
Associate Editor
Marketing Communications Leader, Global MR

Anna Brown
Associate Editor
Marketing Operations and Brand Management Director, Global MR

Mary Beth Massat
Associate Editor

Heide Harris
Clinical Editor
Clinical Marketing Applications Training Manager, Global MR

Steve Lawson
Clinical Editor
Clinical Marketing Manager, Global MR

RocketLawnchair
Design & Production

GE Contributors:

Rishi Awasthi
Regional Product Manager, MR

Brian Burns, PhD
Senior Scientist, MR

Anne Davidson
Sales Specialist, MR

Ozgur Demirkilinc
Clinical Leader, MR

Subodh Divgi
National Product Manager, MR

Thomas Doring
Clinical Product Manager, MR

Almos Elekes, PhD
Product Marketing Manager, Global PET/MR, Oncology and Molecular MR

Eduardo Figueiredo
Clinical Development Specialist, MR

Yu Kaibara
Product Marketing Manager, MR

Doug Kelley, PhD
Product Manager, Global 7.0T MR

Brian King
Regional Modality Leader, MR

James McMahon
Senior Director, Regulatory Affairs, MR

Sabina Prato
Customer Success Leader

Fraser Robb
Manager, RF Coils, MR

Glen Sabin
Director, Regulatory Affairs, MR

James Sedorovich
Clinical Product Marketing Leader, MR

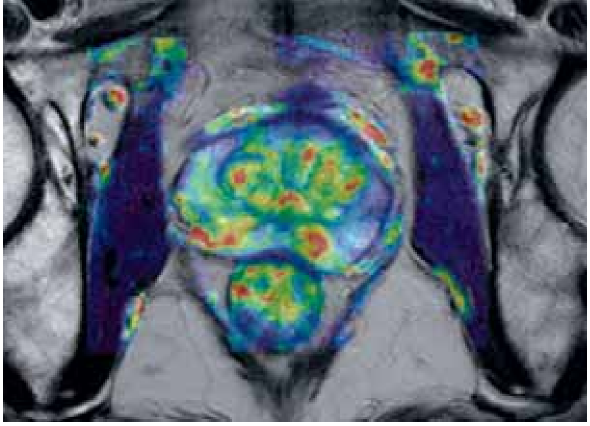
Bob Stormont
Principal Engineer, MR

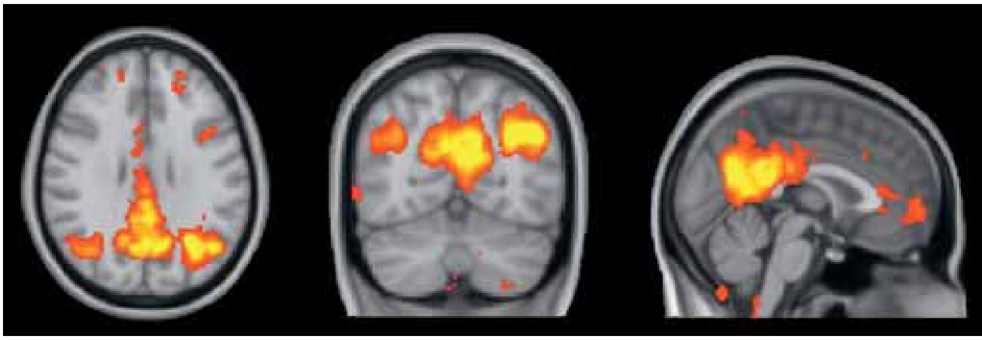
Vineeth V.S.
Advanced Lead Clinical Specialist, MR

Xiao Wang
Product Marketing Leader, MR

Dan Weyers
Product Manager, RF Coils, Global MR

Hendrik Wolfs
General Manager, 3.0T MR Segment Engineering





Case Studies

Tech Trends

© 2018 General Electric Company, doing business as GE Healthcare. All rights reserved. The copyright, trademarks, trade names and other intellectual property rights subsisting in or used in connection with and related to this publication are, the property of GE Healthcare unless otherwise specified. Reproduction in any form is forbidden without prior written permission from GE Healthcare.

LIMITATION OF LIABILITY: The information in this magazine is intended as a general presentation of the content included herein. While every effort is made by the publishers and editorial board to see that no inaccurate or misleading data, opinion or statements occur, GE cannot accept responsibility for the completeness, currency or accuracy of the information supplied or for any opinion expressed. Nothing in this magazine should be used to diagnose or treat any disease or condition. Readers are advised to consult a healthcare professional with any questions. Products mentioned in the magazine may be subject to government regulation and may not be available in all locations. Nothing in this magazine constitutes an offer to sell any product or service.

Celebrating 35 years of MR leadership

Over the last 35 years, GE Healthcare has developed incredible breakthroughs that have changed the MR industry. The last five years have proven to be some of the most productive in our history, from higher powered gradients to the latest AIR Technology™ Coils. These MR advances impress even the engineers who develop them.

After three decades of developing MR technology with GE, Bob Stormont, Principal Engineer, still can't believe it.

"The physics of MR is extremely complicated. Getting the technologies to work in concert and create an MR image is really stunning. It's almost magical that we can do that, and I'm still stunned every time I look at an MR image," says Stormont.

Rikk Wolfs, General Manager, MR 3.0T Segment Engineering, joined GE in 1996 and is continually amazed at the speed of innovation. "Every time I think we've reached the end of the line in some feature of the system, we come up with the next big thing," he says. "It's truly a credit to the team here that they're able to conceive of these things in the first place."

A history of innovation

MR has come a long way since the early days of development. Thanks to the efforts of GE scientist Dr. John Schenck and his research team, GE launched the SIGNA™ 1.0 in 1983. The 1.5T whole-body system made history as the first commercially available MR scanner.

Since then, each year reinforces GE's excellence in MR, and the last five years have simply accelerated that innovation. Stormont and Wolfs say several recent developments are both indicators of past success and signposts to the future of MR.

SIGNA™ Premier is at the top of their list. GE's latest 3.0T MR scanner is the most powerful SIGNA™ MR ever, delivering high-quality neurological, liver, cardiac, prostate and breast images. It's an advanced MR system equipped with innovative coil and gradient technology that directly links to cloud-based analytics.

"The SIGNA™ Premier is the best system and software that we've ever put out. I don't think any of our customers have explored its full capabilities yet, but we expect they will soon," says Wolfs.

AIR Technology™ Coils are another highlight. The revolutionary, lightweight coil design comfortably conforms to a patient's body and is less cumbersome for technologists to position, yet delivers the high-density channel count for excellent image quality.

Wolfs and Stormont agree that GE's culture of innovation and a spirit of collaboration were the keys to bringing developments like AIR Technology™ to life.

> “It’s truly a credit to the team here that they’re able to conceive of these things in the first place.”
>
> *Rikk Wolfs*

“Cross-pollinizing across the modalities is critical,” Wolfs says. “I see that happen frequently when people are faced with a technical problem and wind up rummaging around in some previous experience they’ve had, or talking to somebody that might have solved a similar problem in the past, and that will get them through the hurdle.”

The next 35 years

Wolfs expects MR to embrace cross-modality imaging. He points to PET/MR as a defining moment in the trajectory of MR technology and a key to its future. “I think MR will start leveraging its chemistry capabilities in a more effective fashion, such as in PET/MR and new molecular imaging techniques such as C-13 hyperpolarization[‡],” he says.

MR technology is moving so fast that it’s hard to predict what’s next, but both engineers agree that artificial intelligence (AI) is a when, not an if.

“There might be a new generation of faster or lower field systems that could use AI to get diagnostic quality images, which could make MR more available to the world,” says Stormont.

Wolfs says this could have a huge impact on patient care in remote areas and developing countries where MR is difficult to access. “If we could find a way to get those folks access to MR scans, it would improve their lives immeasurably. I think that’s where a lot of this newer technology is going to take us,” says Wolfs.

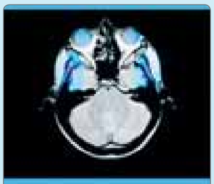
He also expects AI and machine learning to greatly reduce the technologists’ workload by simplifying machine operation. “I think that’s going to be our next big leap forward, where we’re focusing on the technologist and making their lives simpler,” Wolfs says.

Whatever the details, Stormont and Wolfs are ready to transform MR technology—again.

“It seems that about every five years, MR becomes an emerging technology again, which is really remarkable,” Stormont says. “I think it’s because the opportunities are still wide open for what will happen next.” S

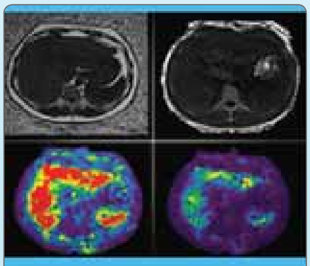
* Hyperpolarized C-13 imaging agents may only be used for human applications under an approved research study (IND or equivalent).

First high-field 1.5T scanner
1983

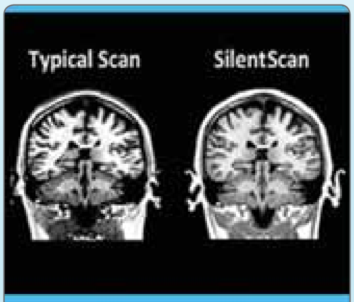


First Fast Spin Echo
1991

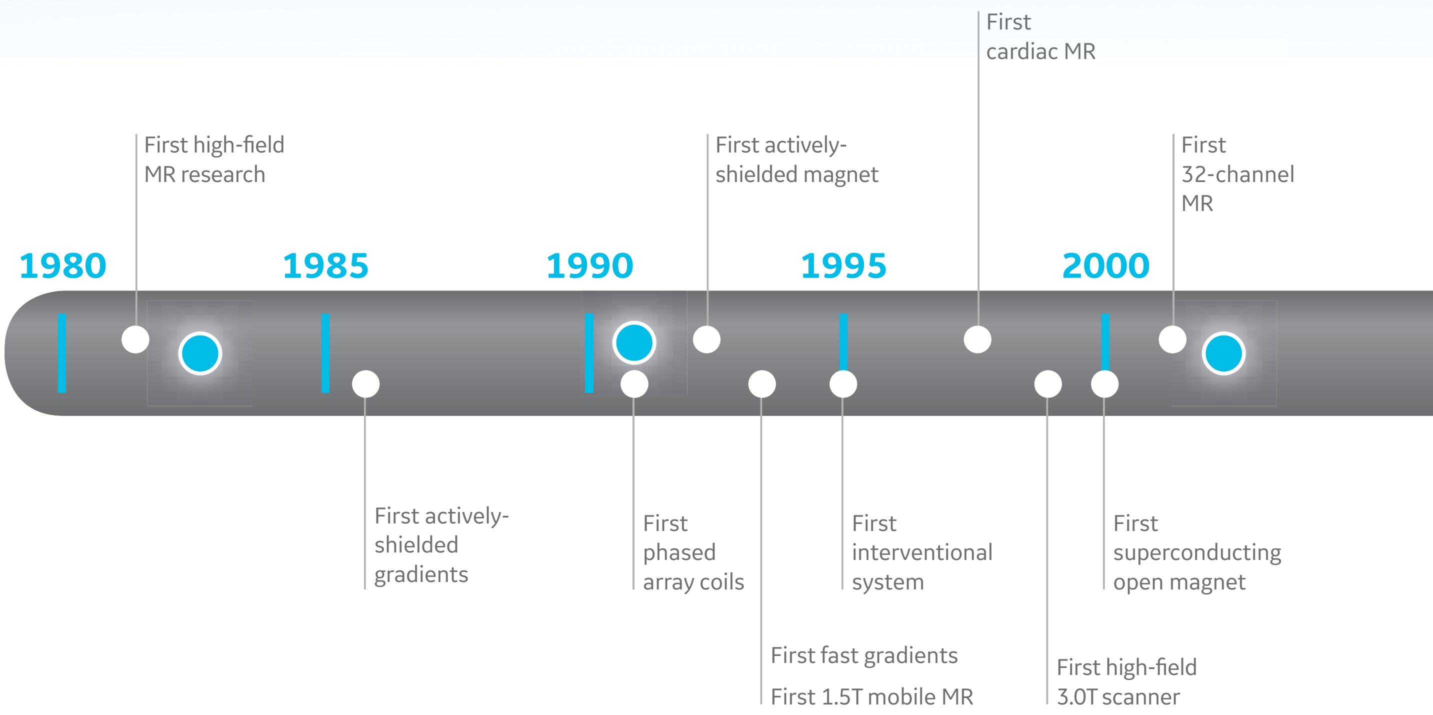
First high-field 7.0T MR
2002



First liver stiffness and quantitative assessment
2009



First silent acquisition technique
2012



35 *Years of MR Leadership*

First Time-of-Flight PET within a wide bore 3.0T MR

2014

Introduction of compressed sensing technique

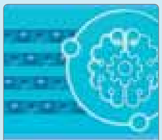
2016

Introduction of AIR Technology™

2017

First intelligent SAR management

2017



Introduction of AIRx™‡

2018

First retrospective motion correction technique

Highest magnetic field MR at 9.4T

First 3D, time-resolved imaging

First MR-guided Focused Ultrasound solution

2005

First MR radiation oncology planning solution

First fat and water separation

2010

First quantitative non-contrast perfusion

First correction technique for the presence of metal

First real-time motion-corrected 3D imaging

First 2D selective excitation diffusion imaging

2015

First synthetic MR technique

First cloud-based MR processing solution

Introduction of rapid 3D dynamic imaging

Introduction of HyperBand Diffusion and DTI

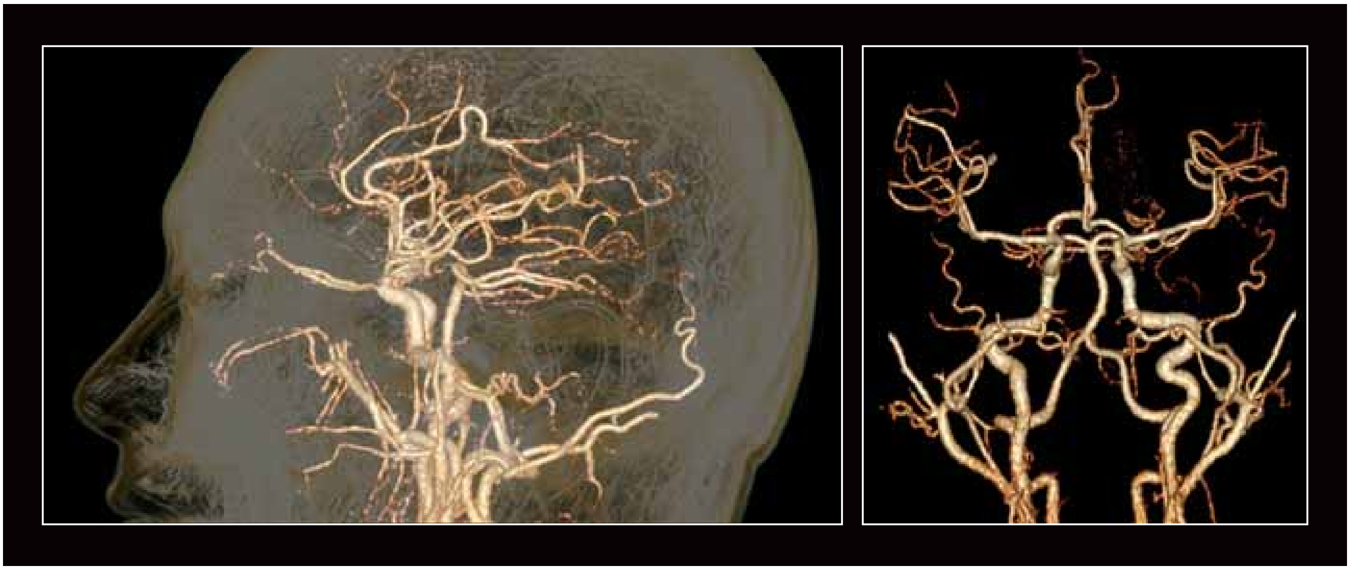
Introduction of low-helium dependent magnet

Introduction of SuperG

Introduction of AIR Touch™

2020

‡510(k) pending at the US FDA. Not available for sale in the United States. Not CE marked. Not available for sale in all regions.



Study demonstrates the value of ZTE MRA in aneurysm follow-up cases

Zero echo time (ZTE) MR imaging is a new pulse sequence that enables ultra-fast, silent imaging for structural, functional and quantitative imaging in neuro applications. A recently published study demonstrates the clinical feasibility of this technique for use in MR angiography (MRA) in cases of aneurysm clips.

Shang et al, evaluated the image quality of ZTE MR compared to Time-of-Flight (TOF) MRA in 25 patients who underwent endovascular embolization for the management of an aneurysm. Digital subtraction angiography (DSA) was used as the standard reference for post-operative follow-up. While aneurysm clips are a common surgical treatment for brain aneurysms, follow-up assessment of the coiled aneurysm is recommended due to the potential for recanalization, which can be as high as 40 percent.[1]

MRA images were acquired 24 hours before DSA and ZTE MRA were performed prior to TOF MRA. Source images, maximum-intensity projection (MIP) and volume rendered (VR), of both MRA sequences (ZTE and TOF) were independently and blindly evaluated together by two neurologists with collectively 35 years of experience. Susceptibility artifact intensity, flow signal and occlusion status were evaluated.

Both patent artery depiction and flow signal mean scores were higher for ZTE MRA than TOF MRA. Fewer susceptibility artifacts were detected in ZTE than TOF MRA. The authors reported that ZTE MRA improved the visualization of adjacent vascular structures and was less sensitive to coil-induced susceptibility signal loss than TOF MRA. Inter-observer and intermodality agreement were both higher for ZTE MRA than TOF MRA. The authors reported that ZTE MRA is a robust sequence they found to be superior to TOF MRA for assessing occlusion status and visualizing parent vessel structures, regardless of coil visibility, and it showed excellent agreement with DSA.

Reference

1. Shang S, Ye J, Luo X, Qu J, Zhen Y, Wu J. Follow-up assessment of coiled intracranial aneurysms using ZTE MRA as compared with TOF MRA: a preliminary image quality study. Eur Radiol. 2017 Oct;27(10):4271-4280.

AIR Touch drives consistency and eliminates variation in scan prescription

GE Healthcare introduces AIR Touch™, an intelligent coil localization and selection tool. It enables automatic coil element selection that is unique for each individual patient and anatomical area that is being scanned.

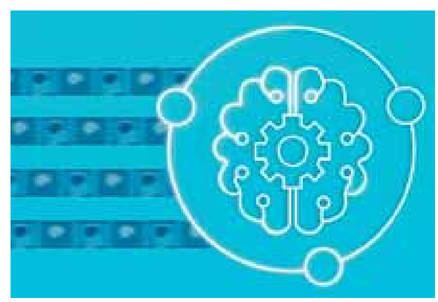
As the bridge between AIR Technology™ Coils and the MR system, AIR Touch™ informs the system when the coil is connected, allows the technologist to landmark the patient with a single touch and even optimizes the element configuration. Coil coverage, uniformity and parallel imaging acceleration are generated dynamically to optimize image quality. A simplified user interface allows the technologist to focus on the patient and also maximize examination efficiency.

It is adaptable to every patient regardless of anatomy, pathology or patient age. With AIR Touch™, every technologist can get the best possible image for every patient. S

Introducing intelligent MR powered by deep learning

Information about the patient and their health are important considerations throughout the care delivery process. From the reason for the exam to the signed radiology report, integrating this information enables the radiologist and referring physician to piece together the puzzle that comprises each patient's injury or disease. But what about the exam? Just as radiologists need information to make the best possible diagnosis, technologists also need information to generate the best possible imaging study.

That's where intelligent MR powered by AI comes in to automate the imaging process. **AI**Rx™‡ is more than AI. It's assisted intelligence for every technologist. It is designed to allow for automated, consistent, fast and patient-specific prescription in neuro exams, and is operator independent. Precise slice placement helps enhance productivity as technologists can improve throughput and reduce retakes. Reduced variability can also help improve radiologists' efficiency and diagnostic confidence in MR exams and easier reading of follow-up scans.



Deep learning algorithms train and rapidly identify anatomical landmarks for simplified setup. Because it incorporates both AI and deep learning, the unique training dataset benefits from transfer learning. **AI**Rx™ is so intelligent that it can help provide consistent results independent of the position of the anatomy being scanned. S

‡ 510(k) pending at the US FDA. Not available for sale in the United States. Not CE marked. Not available for sale in all regions.

Sharing ideas that foster innovation

At GE Healthcare, we're committed to fostering ideas and innovation. Our partnerships with academia extend beyond product development to exploring new ways of approaching MR imaging using the latest technologies—artificial intelligence, machine learning or cloud computing power—to examining ultra-high-field and functional imaging. SIGNA™ Masters is your connection to the latest research and innovation at GE MR.

GE MR's inaugural SIGNA™ Masters Neuro Summit was held in partnership with our colleagues at King's College London May 21-23, followed by our PET/MR Summit in Philadelphia, PA, in June.

SIGNA™ Pulse of MR sat down with Almos Elekes, PhD, Global Product Marketing Manager, PET/MR, Oncology and Molecular MR at GE Healthcare, to talk about the PET/MR Summit.

Q. Why did GE develop the SIGNA™ Masters program?

A. We did it to foster collaboration between our customers and GE as well as educate current and future customers about our scanners and related clinical and research use. A key goal was to share best practices with and by technologists and physicists.

Q. What did clinicians and physicists gain by attending the PET/MR Summit?

A. It's really important that clinicians can see how other sites are using the SIGNA™ PET/MR for clinical research and routine imaging from around the world. Clinicians can talk to their counterparts about reimbursement methods and physicists can have in-person discussions with the GE physicists and engineers about technical details of the scanner. Overall, it is expected that physicians, technologists and physicists will be enriched by attending.

Q. What was your "best" moment of the June PET/MR Summit?

A. All the networking and sharing... that was really great to see happen. For example, we had a physician from a leading US institution who was impressed by a Japanese physician's work in the lung, so they exchanged contact information to talk about it further after the summit.

Q. We understand that workflow and intelligent MR were hot topics at the June event. How is GE helping clinicians to create an efficient and productive workflow in PET/MR?

A. Different institutions and countries have different practices and guidelines, especially on dose management of PET in PET/MR imaging. Some countries' workflow management are excellent and physicians from these regions shared their best practices.

Q. How can SIGNA™ Pulse of MR readers stay informed of future events?

A. As a member of the SIGNA™ Masters community, you can stay informed of the latest updates on industry trends, innovations and related global events. Stay in the loop. We have a lot of exciting engagements and content planned in the coming months, so please bookmark **www.gehealthcare.com/signamasters** and check back with us frequently.

SIGNA MASTERS

Sharing ideas that resonate

They say it takes a village to raise a child. When it comes to healthcare, it takes a community to make a difference in patient care. Expanding upon our SIGNA™ brand philosophy, the SIGNA™ Masters program encapsulates the spirit of innovation, serving as an exclusive community of MR experts coming together to share best practices, conventional wisdom and industry insights. It's this strength in numbers that helps us continue to lead the charge in MR.

Become a member of this exclusive community today. You'll be amazed with what we can accomplish together.

Watch videos from recent SIGNA™ Masters events at www.gehealthcare.com/signamasters.

2018 ISMRM Lunch Symposium, Paris

Our first experience with SIGNA™ Premier

Stefan Skare, PhD
Karolinska Institutet

Recent advances in MSK MRI

Hollis Potter, MD
Hospital for Special Surgery
Weill Medical College of Cornell University

Adding value to MR imaging using AI

Greg Zaharchuk, MD, PhD
Stanford University

2018 Neuro Summit, London

GE NFL Head Health Initiative

Teena Shetty, MD
Hospital for Special Surgery

Bringing advanced diffusion MRI to the clinic

Flavio Dell'Acqua, PhD
King's College London

Physiological MR imaging of brain diseases

Marion Smits, MD, PhD
Erasmus MC, Rotterdam

New Editorial Board Members for SIGNA Pulse of MR

SIGNA Pulse™ of MR introduces new editorial board members for 2019. We also have added the position of Guest Editor to our line-up. The editorial board of SIGNA™ Pulse of MR is proud to announce the appointment of Allen Song, PhD, as the magazine's first Guest Editor.

Allen Song, PhD, Professor in Radiology, Duke University School of Medicine and Director, Duke-UNC Brain Imaging and Analysis Center (BIAC)

Dr. Song has been using GE Healthcare MR systems for 28 years since he was a graduate student at the Medical College of Wisconsin (MCW). One of his most memorable experiences working with GE was while at MCW. He had the opportunity to attend weekly sessions at GE, listening to experts discuss cutting-edge MR imaging techniques. It was during this time that his fascination with MR began.

"I may very likely have been the first human subject for BOLD fMRI when Peter Bandettini and the MCW team were conducting very early investigations on the BOLD contrast," Dr. Song says. This successful experiment took place in one of the GE MR test bays in Waukesha.

Dr. Song has been a collaborator with GE MR throughout his career. A key highlight for him was working with Duke University colleague Nan-Kuei Chen, PhD, Associate Professor of Radiology, and former student Arnaud Guidon, now an MR Scientist at GE Healthcare, to bring the high-resolution DWI sequence MUSE from the laboratory to the clinic. Interestingly, Duke University Medical Center was the very first installation of GE's SIGNA™ 1.0, a 1.5T MR system, nearly 35 years ago.

For Dr. Song, who was trained in electrical engineering as an undergraduate student, MR offers him the perfect combination of engineering and medicine. Looking forward, he is excited at the potential that both precision and personalized medicine can bring to healthcare, specifically the opportunity for disease-specific image acquisition and analysis packages that could provide early imaging biomarkers for treatment planning.

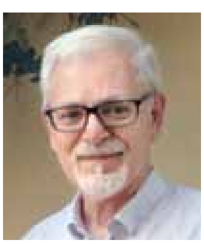
Jason Polzin, PhD, General Manager, Applications and Workflow, GE Healthcare

After earning his PhD in medical physics at the University of Wisconsin, Jason Polzin joined GE Healthcare MR and has been here ever since. He has held a variety of positions including PSD engineer, ASL scientist and Chief Engineer before his current role.

Jason is the inventor/co-inventor on 25+ patents including Time Resolved Imaging of Contrast Kinetics (TRICKS) and as a PSD engineering and ASL scientist, he developed product features for PSD and recon, most notably efgre3D, FastCard, FastCine, elliptic-centric scanning, FMPVAS, SmartPrep, and dB/dt optimization.

He credits a tour at GE MR while he was an undergraduate with the head of ASL at the time, Rich Kinsinger, with sparking his interest in MR. Although Jason has travelled all over the world, visiting the West Bank in Israel during the Elscint integration is his most memorable experience. And he's most proud of being a part of a number of product launches with GE, including the 1.5T SIGNA™ Excite system in 2001, Discovery™ MR750 in 2008 and the first noise-free MR, SilentScan, in 2014.

When asked about the next five years, Jason cites a famous quote from Bill Gates: "We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten." So while he thinks AI will have a major impact, Jason believes it will most likely be in ways that we least expect.



Guillermo Zannoli, PhD, Clinical Marketing Manager, MR Europe, GE Healthcare

Guillermo has worked in many different roles within the MR business—PSD programming, research support, marketing, sales and applications. He has sold MR scanners in places as distant and different from each other as Pakistan, South Africa and Iceland. And the irony of his long, successful career with GE is that he didn't choose to pursue the field after graduating with a PhD in physics; it was a stroke of luck, he says… one that made his professional life extremely interesting and rich.

In his 30-plus years with GE Healthcare MR, he recalls collaborating with Professor Ian Isherwood (Univ. Manchester, UK) in the early years of clinical MR, as his most memorable experience. Guillermo is very proud of his team of European MR clinical leaders, for the values they share, the help they bring to GE's customers to serve patients better, and the clinical results they produce.

Guillermo has watched MR systems become affordable, almost ubiquitous and valuable in most clinical areas. And while good quality examinations require skillful technologists and cooperative patients, the real challenge will be to develop scanners that can operate in the hands of inexperienced technologists and produce consistently good images on any patient.

Ersin Bayram, Manager, PhD, Body & Oncology MR Applications, GE Healthcare

Ersin, who has a PhD in Biomedical Engineering, started his GE career as a development engineer in the Pulse Sequence team. Seven of his inventions are in use in GE MR products today. He believes that MR not only broadened his horizons as a scientist but also allowed him to travel and get to know other cultures. So far, he has visited 17 countries while with GE.

During his first year of his doctorate program rotation, Ersin was exposed to different research tracks, including MR. He was so amazed with the technology that he decided to work on MR for his PhD dissertation and the rest, he says, is history.

The most impactful moment working at GE was when he observed a pediatric MR exam that involved an infant. That moment really put everything in perspective for him about the impact of his job for customers, patients and their loved ones.

Ersin always enjoys seeing the applications that his team developed in the hands of GE customers… it's a moment of joy and pride for him because he knows he is making a difference in the moments that matter most. He is equally excited to see how artificial intelligence will change productivity in healthcare, especially in MR.

R. Scott Hinks, PhD,
Chief Scientist, GE Healthcare

Scott entered MR in 1985 as a Postdoctoral Fellow after completing his PhD in Chemistry at the University of Toronto. A unique postdoctoral opportunity to switch to MR was presented to him, and although he did not know much about MR at the time, it looked interesting. The potential for his work to directly benefit patients with better diagnoses and healthcare made it too good to refuse. He recalls that at the time, a colleague assured him that MR was a fairly mature field and that he should keep his options open. It took him about five years to throw away his chemistry journals, realizing the field was far from mature with much potential for the modality.

As with many long-time GE scientists, he has traveled extensively: 49 of 50 states in the US and 21 visits to China, learning enough Mandarin to get by in China. Most of Scott's work has been in MR systems and physics, including eddy currents and artifacts. In addition, he had the privilege as a young scientist at GE in 1990 to develop Fast Spin Echo (FSE) into a product sequence. Almost overnight, FSE took an 18 minute T2 exam down to about 4 minutes! He has worked extensively with the academic community and recalls his work with the GE China team to build a strong research support team and community in the country as one of his most memorable opportunities.

Looking forward, Scott believes the application of AI methods will revolutionize how MR is used and performed, from workflow and scan productivity to better and more consistent images. He sees it advancing decision support, helping improve radiologist efficiency and providing new diagnostic and prognostic information across a growing number of disease conditions.

Katrin Herrmann, PhD,
Global Product Marketing Manager,
MR Applications and Visualization,
GE Healthcare

Katrin earned her PhD from New York University, Center for Neural Science and Psychology & Center for Brain Imaging. She has lived and worked in both Germany and the US, and has held roles at GE as a research manager and marketing manager. As a Regional Research Manager, she has built up and managed academic research collaborations across modalities and clinical fields in various European countries. Katrin was interested in understanding how the human brain processes visual information while studying for her PhD, and chose to work in the field of MR as she has continuously been amazed by how MR can help understand the human brain and body.

Her favorite moments at GE have been working closely with customers who are using GE's software and technology advancements in research and in clinical practice to improve patients' lives.

Katrin is excited to address current challenges in healthcare: she believes that quantification in MR can improve clinical outcomes and will propel precision health, and that the use of data analytics, AI and cloud-based platforms can help customers in their clinical, financial and operational decisions.

Moving the needle in coil development: the vision behind AIR Technology

For more than a decade, the patient experience has been at the forefront of product research and development at GE Healthcare. The initiative to humanize MR with the launch of the Caring MR Suite and apps like SilentScan was clearly focused on addressing one of the key limitations of MR imaging: patient discomfort and non-compliance due to claustrophobia, noise and bulky, heavy coils.

Fraser Robb, Chief Technology Leader for MR Coils, says, "We started a project almost 10 years ago with the goal of developing the ultimate blanket coil. We had looked at other concepts because we found traditional hard shell coils often severely restricted patient size. In the end we realized we can't beat physics. The coils have to be close to the patient to capture the electromagnetic radiation coming from the patient."

Bob Stormont, Principle Engineer, and Robb, are both part of a laboratory that looks at advanced technology for product roadmaps—the next generation and beyond.

"We were interested in extremely flexible and lightweight coils," Stormont says. "We always believed we could develop what became AIR Technology™."

It was just a matter of getting there.

Stormont was leading a team of engineers that looked at how they could accelerate coil development and possibly leap forward to land where they wanted to be—a flexible coil that could conform to the body and challenge the longstanding limitations of traditional rigid coils.

The team set their sights on the highest attainable goal: lightweight and ultra-flexible.

"From the start, the vision of this project was to improve how our instruments are received and used by customers," says Michael Brandt, Chief Marketing Office, Global MR. "Every day when a patient is in an MR scanner, they experience a certain level of discomfort. If we can help to make them more comfortable and facilitate getting the coils closer to the anatomy, then we can improve image quality to some extent. If we can help technologists to set up the patient in an easier fashion, then we can reduce the number of repeats and make their lives easier."

It boils down to designing the best coil for each body part.

Watch the AIR Technology™ Behind the Scenes Film to learn more about the development of these coils: https://youtu.be/HzjzKnlZMdw

GE Healthcare commercialized the phased array in 1991, yet there are still limits to this design. Robb explains, “The design emphasis was to overcome these traditional limitations of conventional phased arrays, which are heavy, bulky and not flexible, by developing something soft, flexible and pleasing.”

With conventional phased array coils, such as an Anterior Array (AA), the technologist would lay the coil on top of the patient and scan the liver or pelvis, for example. “However, if they wanted to scan a different anatomy, the technologist would have to go back into the scanner room to physically move the coils and re-landmark the patient,” says Holly Blahnik, MR clinical development specialist. “Patients who were too sick or in pain often couldn’t conform to the rigid coils.”

According to Brandt, the development process for AIR Technology™ was strikingly different. The design team had a much broader scope to find a solution to the problem.

“We allowed them the capability to trial this as many times until they got it absolutely right, instead of tolerating a bigger compromise,” Brandt explains.

Never compromise. From the start this was the design team’s philosophy. And every time they found themselves starting to compromise, they started over.

The team began with trying to solve the problems that existed with flexible coils. On numerous occasions, they became trapped by existing design constraints and would inch closer to a conventional solution.

“We realized by doing that, we would end up with a conventional coil,” says Stormont. “So, we would stop, back up and reassess where we were at. And leadership gave us that opportunity. The project was so compelling that even though we would stall, they continued to support us because we could show them the vision of what this could be and convince them we could get over this hurdle.”

Another concept the design team embraced was to move away from coils built like industrial electronics to coils built like clothes or blankets. And, the coil needed to be intelligent.

Explains Dan Weyers, Global Product Manager, RF Coils. “It shouldn’t matter if the technologist was only using five of

30 elements. We wanted each element to be optimized for versatility, so the coil could be used to image different anatomies, shapes and sizes."

For example, if using a conventional coil on a patient with skinny arms or legs, the technologist would have to be careful to ensure the elements didn't overlap. By designing an intelligent coil that could use certain elements and not others, it could be possible to overlap the coil. This capability required an innovative design, where the elements could work closely together to achieve a high SNR and at the same time, not interact or interfere with each other.

Ease of programming the coil was another key development concept. By enabling auto selection of the elements based on the region of interest and body part selected, the team believed they could help the technologist obtain the best possible image quality, Weyers adds.

"The goal of our design concept was not to just image what has been imaged before. Rather, the promise of AIR Technology™ is that we can apply elements and coils to parts of the body that would otherwise be extremely difficult to image," says Robb. For example, the neck, foot and brachial plexus—all areas that are difficult to image with conventional coil technology.

Mechanical constraints forced compromise in prior coil technologies. But not for this project. It took two separate and simultaneous research projects to develop the innovative technologies behind AIR Technology™.

GE's proprietary E-mode electronics reduce current noise, boost linearity and improve tolerance to varying coil loading conditions. It makes the most out of every centimeter to reduce component volume by more than 60 percent. The conductor material for the loop is lightweight and bendable and a series of linked resonators replaces the rigid circuit boards and lumped components that comprise conventional coils.

These two technologies work very closely together to get high SNR with minimal interaction between the two elements.

"That was the breakthrough," says Stormont. "We can select the size of the loops on the anatomy and position the loop where it is needed."

The team didn't stop with the introduction of AIR Technology™ at RSNA 2017. GE has recently introduced AA and Multi-Purpose (MP) Coils at 1.5T and 3.0T. There are additional plans to develop coils specific to other body areas, such as the shoulder and prostate as well as the brachial plexus, which could potentially be used for C-spine exams. There is also an effort to develop coils for use in radiation therapy.‡

Now, there's no turning back. AIR Technology™ is the new future of coil development at GE and based on feedback from customers, they don't want to turn back either.

"They'll hold it and say, wow, what can I scan with this?" says Blahnik. "And I'll ask them what do they want to scan? The excitement is there because they've never seen any coil like this before. It really does feel like a blanket."

Robb adds, "We have also recently shown at ISMRM a work-in-progress concept for creating an MR coil jacket with some outstanding images of the brachial plexus,‡ which is exactly the type of imaging that's so difficult with conventional coils."

Customer reactions keep driving GE's coil design team to continue innovating. There were no expectations with the first prototype, but now the team wants to keep pushing the boundary of coil design limitations.

"This really opens up the possibility of wearable MR coils in the future," Robb says. "Instead of placing heavy industrialized bulky electronics on a patient, we can provide a clothes-like experience to the patient."

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

Utaroh Motosugi, MD, PhD
University of Yamanashi Hospital,
Yamanashi, Japan

A lighter, more flexible and comfortable way to scan

At the University of Yamanashi Hospital in Japan, Utaroh Motosugi, MD, PhD, Associate Professor, Department of Radiology, is focused on research in abdominal MR imaging. Dr. Motosugi has collaborated with GE Healthcare, Richard L. Ehman, MD, Mayo Clinic and Scott Reeder, MD, PhD, University of Wisconsin-Madison using MR elastography and IDEAL IQ.

The importance of this research is underscored by the clinical needs of an aging Japanese society. Cancer, which accounts for nearly one-third of all deaths in Japan, along with Alzheimer's and heart disease, are top concerns for the country's health ministry.[1,2]

Locally, GE researchers often actively work with Dr. Motosugi and his colleagues to explore new technologies and sequences for MR imaging, including SIGNA™ Premier and AIR Technology™.

In March 2018, SIGNA™ Premier and the 48-channel Head Coil were installed, followed by AIR Technology™ Anterior and Posterior Arrays. The hospital already had a good experience with the Discovery™ MR750 in both clinical and research use. According to Dr. Motosugi, the university chose SIGNA™ Premier because of the SuperG gradient capabilities and the new AIR Technology™ Suite.

"We wanted to add a higher performance system that is research capable but also increases patient comfort during scanning," Dr. Motosugi says. "We found SIGNA™ Premier to be the best product for this purpose."

In the first three months of operation, the facility had performed over 400 clinical exams with SIGNA™ Premier, including 284 head/neck, 71 abdomen and 57 musculoskeletal (MSK) exams.

"AIR Technology™ is the biggest technology breakthrough in MR imaging in the last two decades," Dr. Motosugi adds. "It's a key reason to choose a GE MR system."

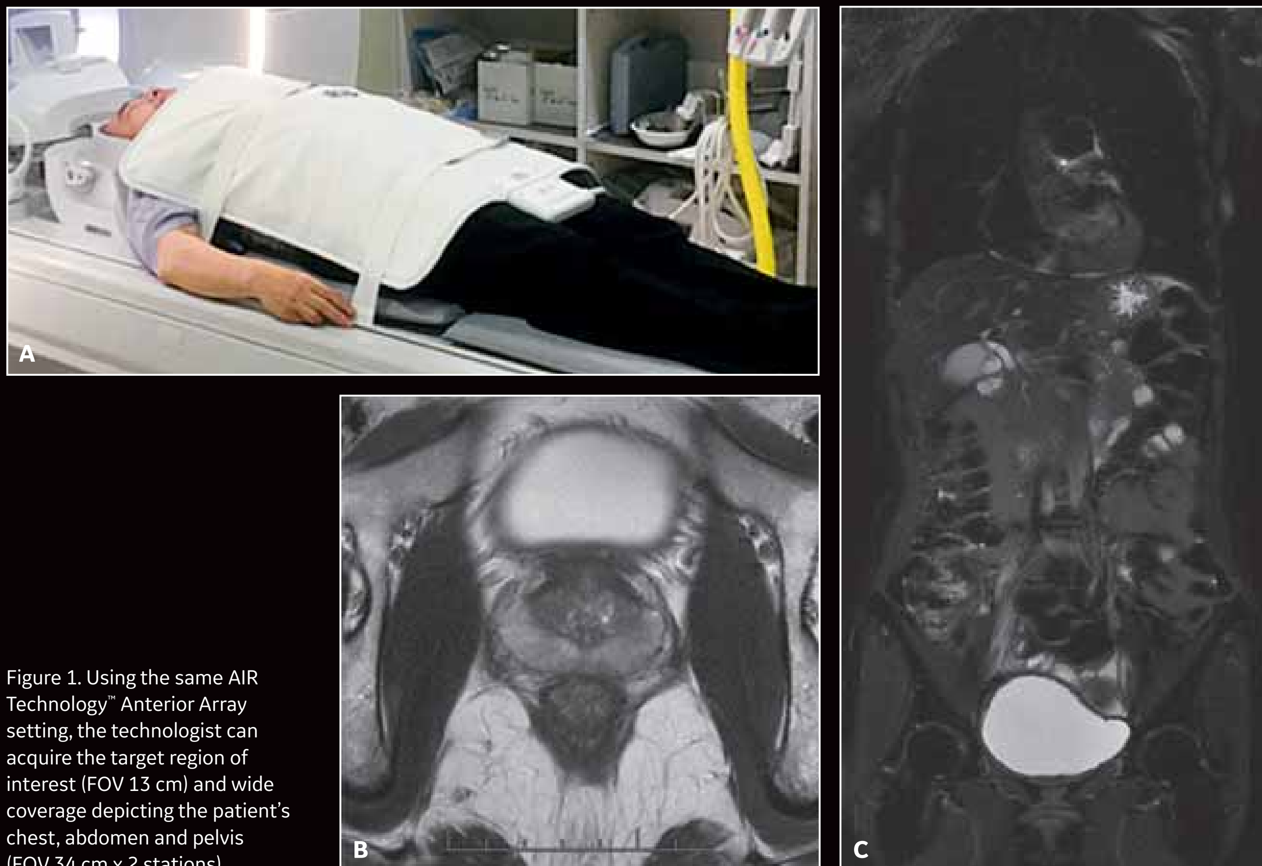


Figure 1. Using the same AIR Technology™ Anterior Array setting, the technologist can acquire the target region of interest (FOV 13 cm) and wide coverage depicting the patient's chest, abdomen and pelvis (FOV 34 cm x 2 stations).

He cites the advantage of patient comfort with the flexible coil but also the high signal penetration and uniformity when imaging deep areas of the body as well as the lower g-factor for faster imaging.

> The AIR Technology™ Suite of coils are 60% lighter than conventional hard-shell coils and are flexible to fit all body shapes, sizes and ages. In these instances, they deliver consistent, high-quality images with higher signal-to-noise ratios (SNR) and freedom in coil positioning by fitting 99.9% of the population.

In brain imaging, the 48-channel Head Coil and SIGNA™ Premier are now the preferred choice at the University of Yamanashi Hospital. Routine MSK imaging with the AIR Technology™ Anterior Array for shoulder, long bone and femoral imaging has delivered very good, uniform images with larger Z coverage than previously attainable.

"While we would like to use SIGNA™ Premier for all of our body work, we have several ongoing liver research studies on the Discovery™ MR750 that include collaboration from other sites throughout the world," he explains. "However, as a body radiologist, I'm eager to run more research on SIGNA™ Premier with AIR Technology™."

Dr. Motosugi appreciates the quality of the facility's existing 3.0T scanner but is excited by the potential from the higher performance and wider bore of SIGNA™ Premier. He also likes the sleek, modern look. With the new coil technology, his first impression is that a conventional MSK coil could be replaced with AIR Technology™ for routine clinical exams.

In abdominal imaging, deep signal penetration with AIR Technology™ Coils in pancreatic imaging has delivered better image uniformity and larger coverage. When imaging specific body areas for lesions, such as the liver or kidneys, it is not uncommon to find a lesion in another area. Prior to AIR Technology™ Coils, this required the repositioning of the coil and/or patient,

Figure 2. Images acquired on a patient with a bladder tumor using AIR Technology™ Anterior and Posterior Arrays. (A) Axial T2w PROPELLER, FOV 20 cm, Th/Sp 5 mm/0.5 mm, 288 x 288 in a scan time of 2:15 min. (B) Axial MUSE with a b1000, FOV 28 cm, Th/Sp 4mm/-2mm, 128 x 256 in a scan time of 2:30 min. (C) ADC Map.

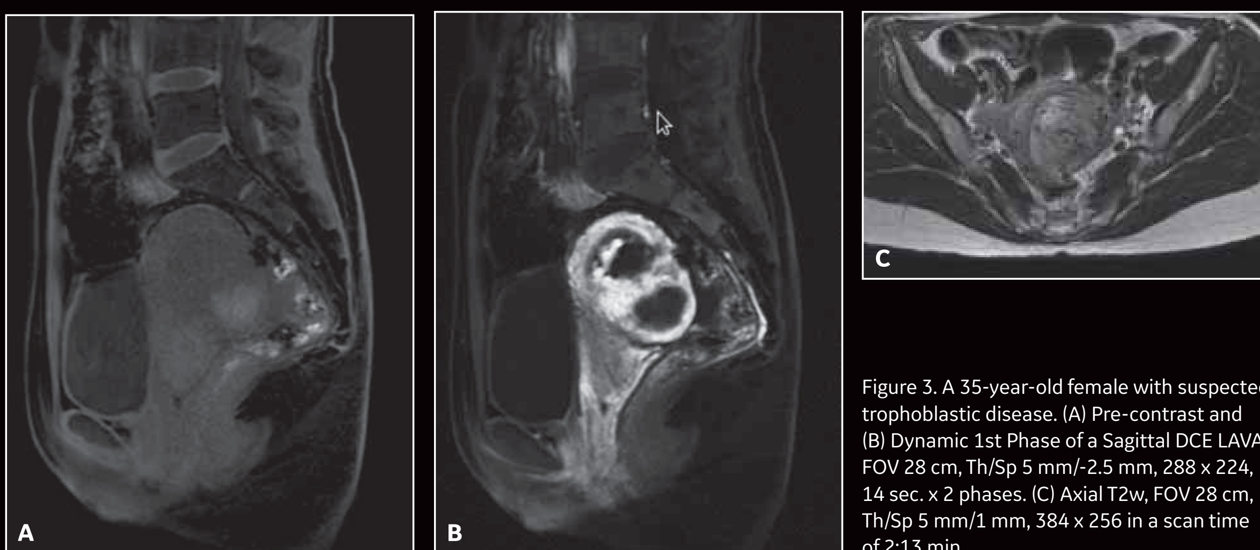


Figure 3. A 35-year-old female with suspected trophoblastic disease. (A) Pre-contrast and (B) Dynamic 1st Phase of a Sagittal DCE LAVA, FOV 28 cm, Th/Sp 5 mm/-2.5 mm, 288 x 224, 14 sec. x 2 phases. (C) Axial T2w, FOV 28 cm, Th/Sp 5 mm/1 mm, 384 x 256 in a scan time of 2:13 min.

taking up valuable imaging time. This is no longer the case with AIR Technology™, leading to higher efficiency and more productive exams.

One area of exploration is the use of AIR Technology™ Coils with 3D dynamic imaging and a reduction in breath-hold time. “We often want to acquire multiple arterial phases for dynamic liver sequences with high image quality. I believe AIR Technology™ will help accelerate higher reduction factors due to the lower g-factor,” Dr. Motosugi says. He also expects to see faster and higher spatial resolution volumetric imaging with the AIR Technology™ Suite. In particular, he anticipates high-resolution volumetric T2-weighted imaging in the abdomen will help him detect small cysts in the pancreas and find the relationship to the pancreatic duct, all in one scan.

In the shoulder, arm and femoral regions, AIR Technology™ Coils have replaced conventional coils for most clinical exams, especially in cases of suspected inflammatory disease. In these types of cases, the clinician needs to visualize a wide area to determine the extent of inflammation.

“Conventional rigid MSK coils cannot provide the coverage we need in cases of inflammation. This is a clear benefit of AIR Technology™.”

Dr. Utaroh Motosugi

Patient positioning in upper extremity exams has also changed with the addition of AIR Technology™. Now, the technologist can position the patient in the center of the magnet for these exams, which further enhances image quality.

Figure 4. Image of a hip-joint depicting femoral head necrosis. (A) T2w FSE Flex Coronal (Water Image), FOV 36 cm, Th/Sp 4 mm/1 mm, 384 x 288 in a scan time of 1:17 min. (B) T2w FSE Flex Coronal (In-phase), FOV 36 cm, Th/Sp 4 mm/1 mm, 384 x 288 in a scan time of 1:17 min.

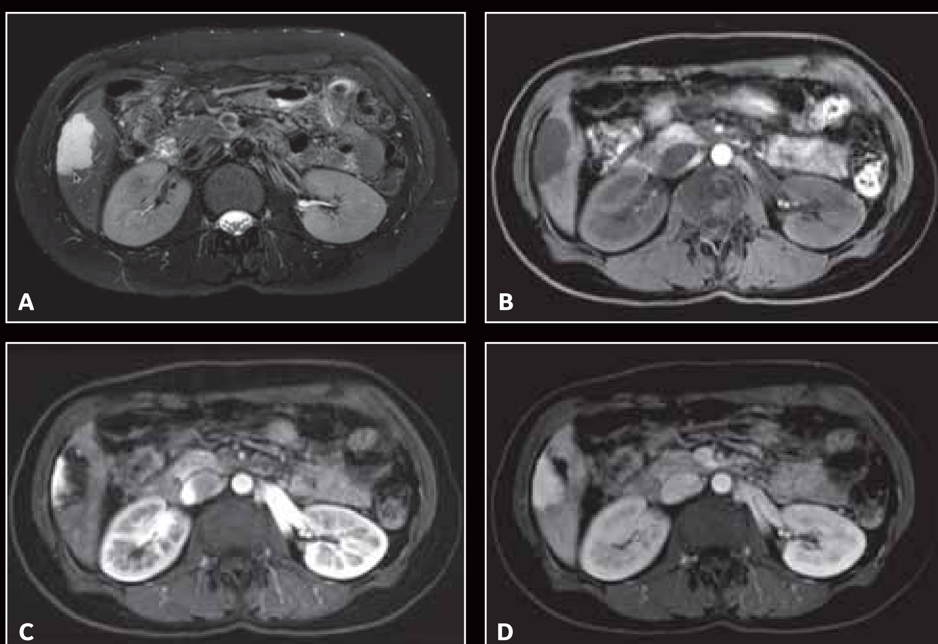


Figure 5. Liver imaging study using AIR Technology™ Anterior and Posterior Arrays to assess a hemangioma. (A) Axial T2w PROPELLER, FOV 30 cm, Th/Sp 5 mm/0 mm, 384 x 384 in scan time of 5:04 min. (B) Pre-contrast, (C) Dynamic 1st Phase and (D) Dynamic 2nd Phase.

AIR Touch™ has also helped the technologists with reducing coil selection errors. It helps technologists determine the best configuration for each patient with an intelligent patient recognition algorithm and system intelligence to automatically optimize every scan, even the element configuration.

Reducing scan times is a key initiative at the University of Yamanashi, as it will free up SIGNA™ Premier for more research-related scanning. The 48-channel Head Coil has helped immensely in this regard, reducing total exam time for a comprehensive neuro exam that includes T1-weighted, T2-weighted, FLAIR, T2*-weighted, DWI and MRA with HyperBand and HyperSense to five minutes. Dr. Motosugi believes this is 50 percent less than conventional 3.0T neuro exam times.

A quality MR system is more than just hardware. Several new sequences for body imaging have also impressed Dr. Motosugi.

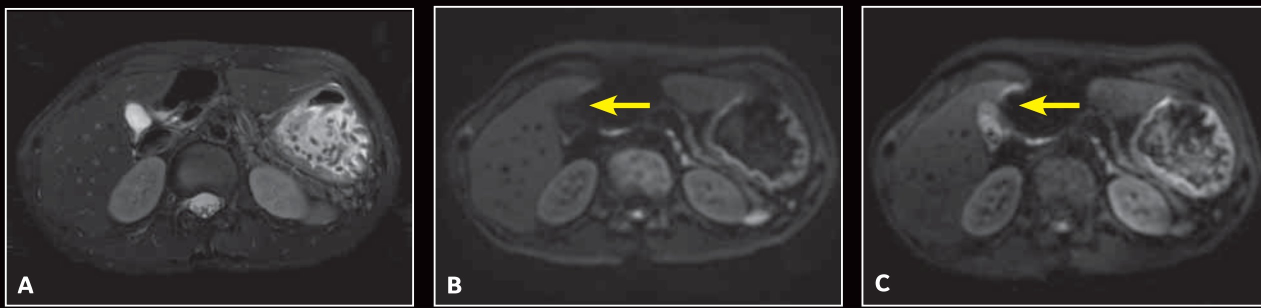


Figure 6. Low distortion DWI is achieved with MUSE. (A) Axial T2w FSE, FOV 30 cm, Th/Sp 5 mm/1 mm, 320 x 320 in a scan time of 2:49 min. (B) Axial MUSE with b1000, FOV 36 cm, Th/Sp 4 mm/1 mm, 128 x 160, shot 2, ASSET 2 in a scan time of 3:30 min. (C) Axial DWI EPI with b1000, FOV 36 cm, Th/Sp 4 mm/1 mm, 128 x 160, ASSET 2 in a scan time of 2:30 min.

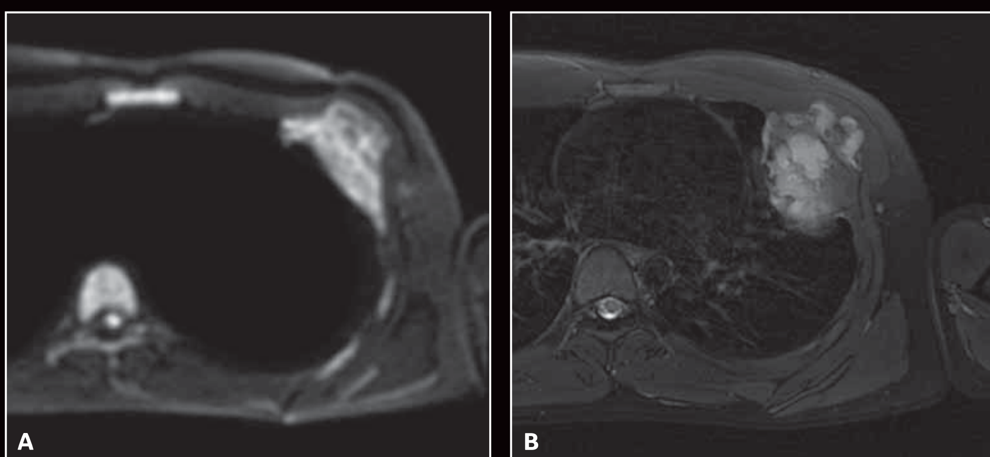


Figure 7. (A) MUSE was utilized for a DWI study of a patient with a suspected bone tumor in the fourth rib. (B) Axial T2w PROPELLER, FOV 24 cm, Th/Sp 5 mm/1 mm 256 x 256 in a scan time of 3:22 min.

"A clear benefit of MUSE DWI is less distortion," he says. In abdominal imaging, MUSE DWI was impressive. When the prior DWI sequence was compared to MUSE DWI, Dr. Motosugi and his colleagues found the older images were more distorted than they perceived at the time, even to the point of impacting a confident diagnosis.

With liver MUSE DWI, there is a reduction in the signal drop that occurs near the stomach. For MUSE DWI renal and adrenal gland imaging, the image quality is excellent in the Coronal plane without distortion. The pancreas is another area with great potential for high-resolution DWI.

"MUSE DWI is also promising in extremity imaging for detecting tumors. We were able to obtain excellent image quality in the knee and shoulder," Dr. Motosugi adds.

The University of Yamanashi is implementing free-breathing abdominal scans thanks to the addition of PROPELLER MB. So far, the imaging has been robust with great image quality.

Yet, the real test of implementing the new AIR Technology™ Coils is the impact it has on the patient experience. The first time they were used, the AIR Technology™ Coils passed the test.

"Surprisingly, the first patient we scanned with an AIR Technology™ Coil said, 'Why is it so comfortable today?' A comfortable examination for the patient is obviously a key benefit of the AIR Technology™."

Dr. Utaroh Motosugi

References

1. http://www.healthdata.org/japan
2. https://www.nippon.com/en/features/h00211/

Dr. Radhesh S.,
MBBS, DMRD, DNB
Celara Diagnostics,
Bangalore, India

Delivering integrated medicine with MR as the foundation for advanced imaging

Dr. Radhesh S., MBBS, DMRD, DNB, Director and Chief of Imaging, founded Celara Diagnostics in Bangalore, India, with the vision to deliver integrated diagnostics to residents throughout the region. By combining diagnostic radiology and laboratory services, the center can deliver a precise diagnosis that can improve care quality while reducing the time and cost to patients. He stands by the center's mission to "achieve excellence in integrated diagnostic patient care by leveraging superior technology, human capital expertise, innovation and teamwork."

As part of that mission, Celara Diagnostics recently installed a 3.0T MR scanner, SIGNA™ Pioneer. The advanced capabilities of 3.0T MR with a higher signal-to-noise ratio (SNR) has enhanced the quality of imaging and diagnostic capabilities, enabling the center to meet the expectations of referring clinicians. Faster scan times with no impact on quality have improved workflow and enabled the center to increase patient volume, providing important imaging services to more patients each day.

According to Dr. Radhesh S., one of the key reasons for choosing SIGNA™ Pioneer was access to innovative HyperWorks applications, part of the SIGNA™Works productivity platform that delivers up to eight times faster results. HyperWorks is comprised of three solutions: HyperSense, HyperBand and HyperCube. HyperSense is a compressed sensing acceleration technique based on sparse data sampling and iterative reconstruction. This application can deliver higher spatial resolution images or reduced scan times, enabling faster imaging without the penalties commonly found with conventional parallel imaging. HyperBand is used for diffusion imaging, which allows the acquisition of more slices or diffusion directions within a typical scan time. HyperCube enables small phase FOV imaging, allowing you to reduce scan times and minimize artifacts such as motion and aliasing by reducing the phase field of view.

Another key benefit is the ability to perform silent exams with SilentWorks, which has helped Celara Diagnostics become established as a special center for pediatric MR imaging. Now, in most pediatric cases, the exam can be performed with the administration of an oral sedative, which has helped Celara Diagnostics significantly reduce the need for IV sedation.

SilentWorks is available across all anatomies and can be done with multiple weightings and coils, including DWI. Zero TE techniques enable imaging of vasculature structures with fewer flow artifacts than those commonly seen with conventional techniques.

Celara Diagnostics also routinely uses PROPELLER MB in brain, shoulder, ankle/foot and female pelvis scans where motion artifacts are a major contributor to repeat studies. Not only is PROPELLER MB helpful when imaging uncooperative patients, including those with uncontrolled movements due to neurological disease or disorders, but it also removes flow artifacts of large vessels. "The fact that we can prescribe any TR and TE values giving truer image contrasts, makes it usable in any situation and gives great flexibility in all body parts," says Dr. Radhesh S. "One of the most differentiating aspects of SIGNA™ Pioneer is that it makes quantification easier with its streamlined post-processing workflow," adds Dr. Radhesh S. "The features that we use frequently for quantification are IDEAL IQ, 3D ASL, CartiGram and Brain Stat."

In addition to simplified quantification, SIGNA™ Pioneer also delivers consistent and reliable MR exams for the radiologists at Celara Diagnostics, especially hippocampal relaxometry, peripheral angiograms, neuro perfusion, cartilage mapping and Quantib Brain quantification.

Neuro imaging

The addition of MAGiC has enabled a more complete exam, particularly in patients suffering from seizures. In the past, T2 relaxometry was often omitted due to the typical six-minute scan time. Now, MAGiC enables the radiologists at Celara Diagnostics to do relaxometry and also synthetically process T1 IR, T2 FLAIR and T2 contrasts within five minutes of scan time.

> "A dedicated high-resolution scan of five-and-a-half minutes will give us everything that we require for a qualitative assessment along with quantitative T2 maps, which we found really helpful to rule out any suspicious signal variations that may mimic sclerotic changes and to doubly confirm the presence of same in the hippocampus."
>
> *Dr. Radhesh S.*

Non-contrast exams using Silenz MRA and 3D ASL are now possible with their new scanner. Silenz MRA is now the preferred sequence for suspected arteriovenous malformations (AVM) cases as it is less sensitive to flow direction, making it more robust than other techniques such as 3D TOF or phase contrast angiograms. As a result, the radiologists at Celara Diagnostics are now more confident in reviewing AVM cases without contrast injection. Similarly, with 3D ASL, radiologists can assess the quality of blood flow in the brain without contrast, detect high CBF in tumors or AVMs and generate functional maps for calculating diffusion perfusion mismatch on READYView, GE's advanced MR visualization platform.

Cerebrospinal flow studies also benefit from the ability to perform peripheral gating instead of using ECG, which requires the technologist to affix electrodes to the patient's body. According to Dr. Radhesh S., peripheral gating can be easily added to a patient's scanning session.

When it comes to detailed neurovascular and brain tumor imaging, HyperWorks has made a significant impact. At Celara Diagnostics, HyperBand helped make DTI a routine procedure. HyperSense shortens the exam time, which provides the opportunity to include more 3D imaging that would have previously been avoided due to the time penalty. And that means more advanced imaging explorations to benefit patients.

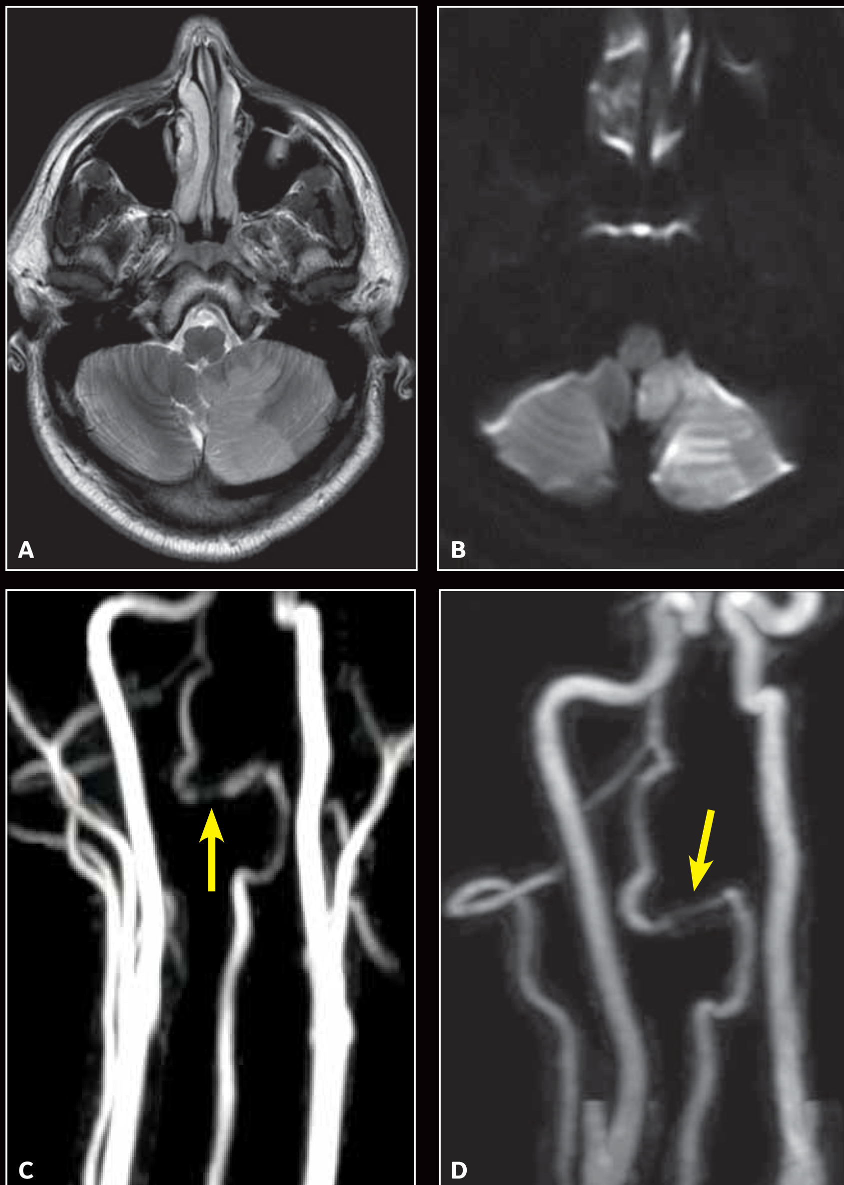


Figure 1. A 35-year-old patient, H/O trauma; head first/supine using the HNU coil. (A) T2w and (B) DWI showing hyperintense areas involving left cerebellar hemisphere postero-infero-medially and inferior vermis with recent onset infarct (left PICA territory). Axial DWI b1000, 160 x 160 in 48 sec. (C) 3D TOF showing a narrowing of the V3 segment of the left vertebral artery (arrow); signal loss in the region is suggestive of slow flow or turbulence. (D) 3D contrast-enhanced MRA TRICKS showing a narrowing of the V3 segment of the left vertebral artery (arrow).

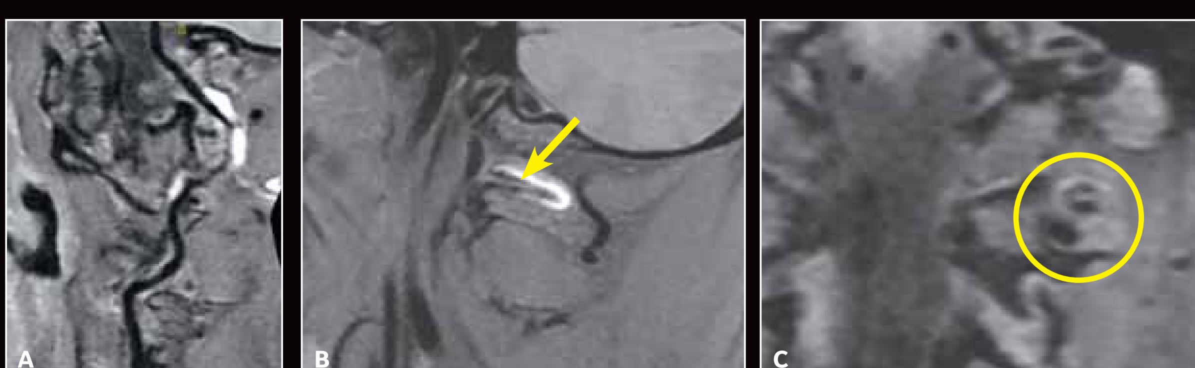


Figure 2. Sagittal Cube T1 HyperSense with a factor of 1.5 with ARC 2x1, 1.2 mm, 400 x 400, 1 NEX and scan time of 4:33 min. (A) Curved reformat demonstrating a narrowed lumen in the V3 segment of the left vertebral artery surrounded by a bright hematoma. Intimal flap is seen in the (B) Sagittal and (C) Coronal view as bright septa in black vessel lumen.

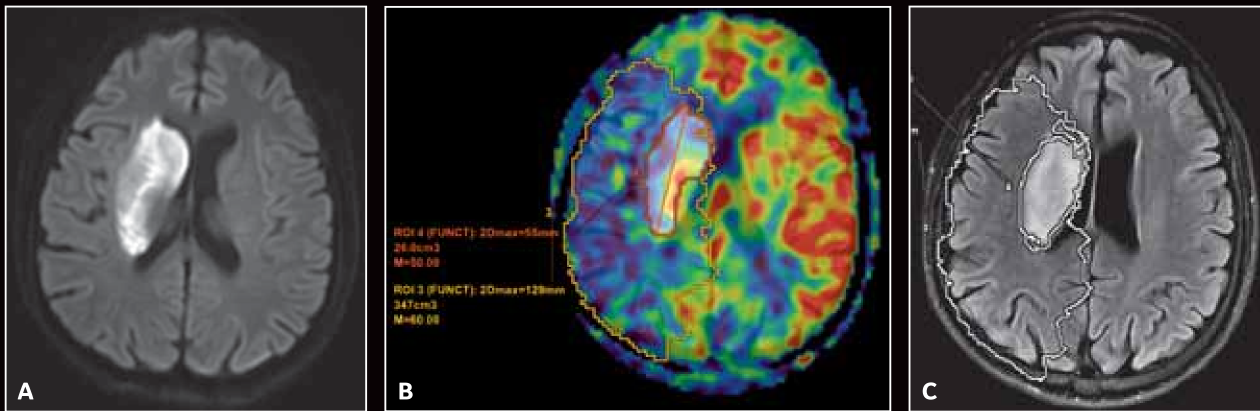


Figure 3. A 35-year-old patient with sudden onset of left-sided weakness. (A) Axial DWI, 160 x 160 in a 48 sec scan time. (B) Fused DWI ASL images showing diffusion perfusion mismatch. (C) ROI overlaid on T2 FLAIR image. ASL was helpful in demonstrating ischemic penumbra noninvasively with color maps and quantified values without the use of contrast.

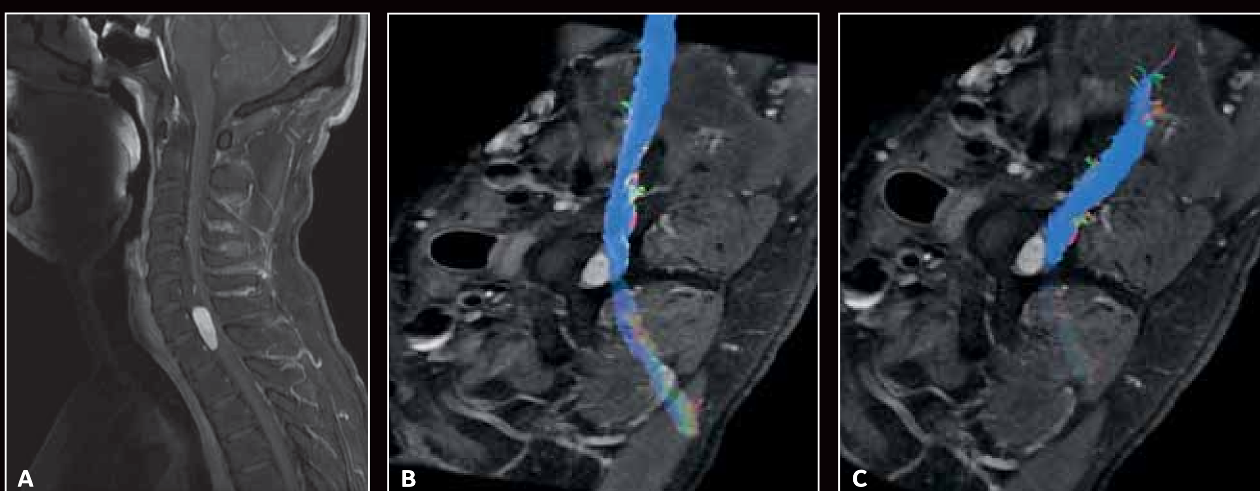


Figure 4. Cervical cord meningioma with DTI. (A) Sagittal T1 IDEAL, 320 x 224 in 3:48 min. (B, C) Fiber tracking done on FOCUS DTI data overlaid over the post-contrast T1 IDEAL showing the tumor displacing the spinal cord posteriorly. FOCUS DTI was helpful in demonstrating the fiber tract of the spinal cord and also its continuity. The distortion reduction achieved with this technique made it easy to overlay the functional maps and fiber tracts on morphological images for better visualization.

Body imaging

Prior to implementing SIGNA™ Pioneer, high-resolution, small field of view (FOV) DWI studies with multiple high b-values was not possible in a reasonable scan time. In many cases, a b-value of 1,000 was used with large FOVs in a scan time of four minutes. Now, thanks to MAGiC DWI, additional b-values can be selected retrospectively without increasing scan times. With FOCUS DWI, the user can zoom in on the anatomy, which is especially helpful for small body parts and areas of susceptibility such as the prostate, pancreas, nerves and spinal cord.

The addition of IDEAL IQ provides a robust and easy-to-use method for obtaining fat and iron quantification in the liver. According to Dr. Radhesh S., IDEAL IQ is more consistent and accurate than conventional techniques that use dual echo and multi-echo sequences, which require comparatively longer processing times and are often more prone to error.

MSK imaging

Shoulder scanning is one area where SIGNA™ Pioneer and GE Healthcare's 16-channel Flex Coils have made a big impact. Not only has the consistency of

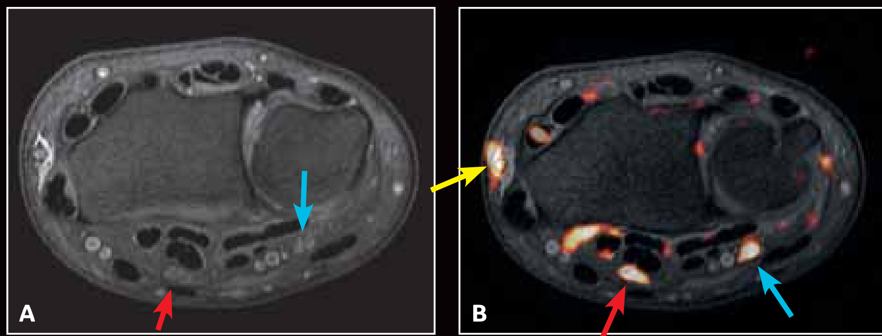


Figure 5. (A) Axial PD FatSat images at the level of the wrist joint demonstrating soft tissue edema on the radial aspect of the wrist joint (blue and red arrows depict the ulnar and median nerves, respectively). (B) Images were co-registered with Axial DWI neurogram images using READYView; ulnar and median nerves were used as reference to confirm nerve involvement. (C) Radial nerve shows a short segment of restricted diffusion proximal and distal to the wrist joint (yellow bracket) suggesting traumatic radial neuropathy.

resolution and image quality improved, but, unlike hard coils, the Flex Coils can accommodate a large spectrum of patients' bodies and sizes. Dr. Radhesh S. adds, "These coils also enable large FOV scans which may be helpful when imaging structures near the shoulder joint without the need to reposition the coil."

Using PROPELLER MB for motion correction has been particularly helpful in MSK imaging and especially in the shoulder. T2 mapping of the knee is also now routinely performed at Celara Diagnostics with SIGNA™ Pioneer.

Neurography is another new exciting area for Celara Diagnostics. "Cube STIR neurograms with a special suppression pulse for slow flowing vessels of the brachial and lumbar plexus are remarkably consistent," says Dr. Radhesh S. Even neurography of small parts, such as the wrist and elbow are diagnostically very valuable. Celara Diagnostics generally uses a combination of Cube STIR and DWI neurograms. In cases with a lot of edema surrounding the region of interest, Cube STIR can become ambiguous; adding DWI helps lessen this effect and also adds a functional imaging aspect to anatomical imaging.

Cardiac and angiography imaging

In non-contrast peripheral imaging, Celara Diagnostics routinely uses Inhance 2D IFIR for vascular screening studies. 3D DeltaFlow is selectively performed in cases with slow flowing reforming vessels. The Inhance 2D IFIR is easy to use; the technologist just positions the patient, adds peripheral gating and performs a fully automatic acquisition. The single-click auto binding feature gives a complete roadmap of peripheral angiography.

For challenging, contrast-enhanced MRA where timing is critical, TRICKS is an ideal imaging technique. It is particularly useful in patients with gangrene or other clinical factors that can cause venous contamination and in cases where venous circulation needs to be assessed. By using the multi-station TRICKS in the Coronal plane, there has been a significant decrease in the need to repeat a station during peripheral runoff examinations. Plus, it provides the flexibility to choose from different contrast enhanced phases.

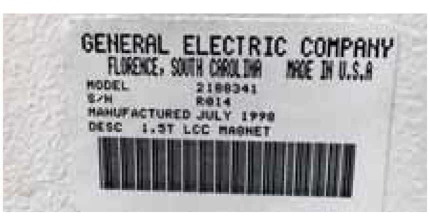
"In our practice we found that injecting a minimal amount of contrast, such as 3-5 ml, before the 2D IFIR scan helps to better visualize small reforming or collateral vessels and, thus, reduces the need for a rescan with 3D DeltaFlow," says Dr. Radhesh S.

Myocardial delayed enhancement (MDE) scans are now more consistent at Celara Diagnostics with MDE Plus, SS MDE and PS MDE. These capabilities have not only reduced scanning time but have also led to higher quality images with a 3.0T scanner even in challenging clinical conditions and with uncooperative patients. The post-processing workflow is faster and more robust, so the center can accommodate cardiac cases even on days with a heavy workload.

With the addition of SIGNA™ Pioneer, Celera Diagnostics can now provide patients with advanced MR imaging and laboratory services for a comprehensive and integrated approach to healthcare. S

Kerry Blatzer, RT(R)(MR)
Intermountain Medical Center,
Intermountain Healthcare,
Salt Lake City, UT

Magnet longevity key to GoldSeal and SIGNA Lift programs



In 1998, Kerry Blatzer, RT(R)(MR), was the MR supervisor at Cottonwood Hospital in Murray, UT, when a new SIGNA™ LX from GE Healthcare was installed. At the time, the system was state-of-the-art and the first short bore MR system that Blatzer and her team scanned on.

The system was loaded with all the latest and greatest features and functionality available at that time. As Blatzer recalls, when the hospital purchased a new high-end advanced imaging system, there would not be additional funds for that imaging modality for quite some time. So, she purchased everything she could with the SIGNA™ LX, including a neurovascular coil for neuro and angiography exams.

"That system was our workhorse for a long time," Blatzer says. "We would do any exam that our clinicians needed. There weren't a lot of options for imaging beyond matrix or echo trains, things like that, but we would make it work. We were pushing the system to get one sequence completed in four minutes, and the entire exam in 45 to 60 minutes."

Over the next 20 years Kerry added software and hardware whenever the budget allowed. A nice feature for the GE MR systems is that they can be upgraded through the GE Continuum™ and SIGNA™ Lift programs. In 2007, GE completed a major upgrade from LX to HDx and this enabled Cottonwood to get another 10 years of ownership and value from their original purchase.

"Until we took that magnet out, it was still a workhorse for us," says Blatzer, who is now Imaging Director of Intermountain Medical Center and corporate lead for MRI Services for Intermountain Healthcare.

In 2018, the original short bore MR magnet was removed from TOSH Intermountain (formerly Cottonwood Hospital) and sent back to GE. TOSH

is making room for a new SIGNA™ Architect 3.0T wide bore MR system to complement a Optima™ MR450w 1.5T that was installed in 2012.

GoldSeal program

The original short bore magnet from TOSH was received and inspected by the GE GoldSeal™ organization. All magnets removed from service are sent to the GE MR facility in Florence, SC, and evaluated for possible refurbishing. According to Jeremy Rady, Segment Manager for the GoldSeal™ MR Business, MR magnets from the GE installed base are evaluated and if they pass incoming inspection, are eligible for GoldSeal™ refurbishment.

"MR magnets can have an impressive, long lifecycle based on original design and manufacturing quality and following proper field service guidelines," Rady explains.

An interesting coincidence is that GE established the GoldSeal™ business in 1998, the same year that Cottonwood purchased their SIGNA™ LX MR system. For more than 20 years GE has been refurbishing pre-owned imaging and ultrasound systems with an emphasis on quality and compliance. Customers from many countries purchase GoldSeal™ with an expectation that their "new to them" system will be reliable, updated and look like a new system.

According to Eric G. Evenson, Lead Account Manager, once a magnet is de-installed and delivered to the Florence, SC, facility, its restoration journey begins right alongside where new GE MR systems are built. Using only original GE parts, every system goes through an exacting, proprietary process to meet original system specifications and performance. GE manages and owns this entire process relying on GE factory-authorized personnel performing to the latest GE specifications. This includes replacing all the covers, plumbing and the body coil. Each refurbished magnet undergoes comprehensive testing and calibration to the same standards used for all new systems and includes a same-as-new warranty.

Today, nearly 1,200 refurbished GoldSeal™ magnets are in use throughout the world. But not every used magnet qualifies for GoldSeal™ status. Newly refurbished systems are considered certified only with magnets that pass all inspections and rigorous testing.

Even when moving to a new location, a practice or facility should inquire if GoldSeal™ is right for them.

> "We had one customer that was going to move their 10-year-old 1.5T magnet from one site to another. Instead, the practice opted for a replacement GoldSeal™ refurbished system at a cost well below what the group had projected."
>
> *Eric G. Evenson*

The GoldSeal™ approach saved the practice the cost of de-installing and transporting the system, as well as the expense of an interim MR system while the existing unit was being moved and reinstalled. GE also worked with the practice to ensure only a two-day gap in MR imaging during the de-commission and new installation, helping the practice to maintain its busy MR imaging schedule. A GE applications specialist provided the necessary training and assisted with protocol adjustments so the practice could take advantage of the new system speed.

More than a face lift

For some customers, there's no need to replace the magnet. That's where GE's SIGNA™ Lift program delivers solutions that can reinvigorate a facility's MR imaging capabilities.

After using the SIGNA™ Excite 1.5T for 12 years, Keiyu Hospital in Yokohama, Japan, decided to upgrade to a SIGNA™ Explorer through the SIGNA™ Lift program in 2016. The original magnet remained but many other components, including the gantry cover, user interface and applications, were all replaced.

At Keiyu Hospital, new protocols available with SIGNA™ Explorer Lift, including PROPELLER, FOCUS DWI and SilentScan, have elevated image quality, shortened scan times and enabled more patients, such as pediatrics, the elderly and claustrophobic patients, to successfully complete an MR exam.

For example, PROPELLER is used for body scanning at the hospital so motion artifacts of the abdominal wall and peristaltic motion of the gastrointestinal tract are prevented without applying strong abdominal pressure. The scan time can be reduced without using the respiratory triggers and the application also helped elevate patient comfort.

With FOCUS DWI, a small FOV makes it possible to obtain DWI images with less distortion and high resolution. As a result, the visualization of the lesion is much improved, especially in the body for prostate imaging cases.

Thanks to SilentScan and Silenz, audible noise is significantly reduced during scanning, increasing the success rate in pediatric scanning. The hospital typically scans infants during their natural sleep state or with oral sedation to induce a resting state.

With SilentScan, only one of 25 patients in the first five months of use woke up during the MR exam, thereby requiring the technologist to stop the scan. The year before on the prior system, seven of 35 pediatric patients woke up during the exam—that's a reduction from 20 to 4 percent.

It's not just new applications that deliver a higher level of imaging capabilities. With SIGNA™ Explorer Lift, Keiyu Hospital can also take advantage of advances in coil technology, such as the Flex Coils. These coils deliver a high degree of versatility, especially in the upper and lower extremities, and can also be used for pediatric spine and contracture patients.

Through the GoldSeal™ and SIGNA™ Lift programs, GE is committed to helping customers get the most out of their MR magnets. While not all will stand the test of time like the 20-year-old magnet at TOSH, it's safe to say that a magnet from the GoldSeal™ and SIGNA™ Lift programs will deliver exceptional imaging capabilities for years—even decades—to come.

Lawrence Tanenbaum, MD
RadNet, Eastern Division,
Baltimore, MD

Donna Mushinsky, RT(R)(MR)
RadNet, Eastern Division,
Baltimore, MD

RadNet skyrockets the patient experience

Just as patients come in different shapes and sizes, so too do MR systems. Not all hospitals and imaging centers need to have the most powerful MR system. Many imaging providers are seeking a workhorse MR system, one that can maximize workflow and productivity while delivering extraordinary clinical potential and exceptional patient comfort.

With 330 imaging centers in six states that, when combined, generate almost eight million imaging procedures, RadNet is the largest provider of freestanding, fixed-site outpatient diagnostic imaging in the US. The company's focus is on delivering high-quality, consumer-focused and cost-effective services by partnering with health systems, medical groups, payors and employers. Leveraging advanced imaging, subspecialists and technology, RadNet provides specialty care in neuro, cardiac, MSK/sports medicine, and cancer as well as dedicated centers for men's and women's health.

Recently, RadNet replaced an older GE Healthcare SIGNA™ MR system with a SIGNA™ Voyager at Advanced Radiology Imaging Center at the University of Maryland St. Joseph Medical Center. SIGNA™ Voyager is a 70 cm wide bore system that has one of the smallest footprints and lowest power consumption in the industry at 1.5T.

"SIGNA™ Voyager is a highly cost-effective, state-of-the-art MR well-suited for the clinical outpatient and inpatient imaging market," says Lawrence Tanenbaum, MD, FACR, VP and Medical Director, RadNet Eastern Division. "Since its introduction two years ago, it has become our default GE 1.5T MR for our network, and we now have at least 12 installed across our sites."

Dr. Tanenbaum is impressed by the power, focus and usability of the system—it isn't padded with added cost for options that don't have an impact on clinical quality and patient care, he adds. Yet, the system employs the newest generation embedded coil arrays which facilitate patient handling and throughput, and the SIGNA™Works productivity platform delivers a portfolio of applications for high-quality, efficient imaging.

Donna Mushinsky, RT(R)(MR), MRI Imaging Specialist, says the embedded coils are an added bonus. "The coils in the table facilitate turnaround time and patient throughput by eliminating

Figure 1. With SIGNA™ Voyager, RadNet can achieve excellent homogeneity in breast imaging. (A) Axial T1 3D, TR=5.7 msec, TE=2.7 msec and scan time of 59 sec. (B) Axial T2 FatSat, TR=2125 msec, TE=101/Ef msec, TI=87 and scan time of 5:15 min. (C) Axial VIBRANT, TR=5.7 msec, TE=2.7 msec, TI=24 and scan time of 1:12 min.

the need to swap out spine and head coils between patients. Body imaging using the Anterior Array far exceeds the image quality of the prior scanner. The Flex Coils are awesome. They can literally be applied to almost any body part and they provide vastly improved image quality over the old hard-shelled surface coils of the past."

SIGNA™ Voyager also features the AutoFlow suite for a more efficient, simpler workflow. Auto Navigator delivers real-time, robust, free-breathing respiratory motion compensation to streamline routine and advanced body imaging. They are compatible with DISCO, Turbo LAVA, Turbo LAVA Flex and GE's entire body imaging suite. Auto Protocol Optimization simplifies and automates breath-hold imaging while enhancing the reliability of image quality and exam duration, regardless of patient profile. Pause and Resume eliminates the need to redo scans or retrace steps, giving technologists greater flexibility to respond to patient needs mid-scan. IntelliTouch landmarking, Auto Guidance and a simple setup with dual touchscreens further enhance the technologist's workflow efficiency and imaging reliability.

For RadNet's radiologists, the READYView quantification and analysis platform reduces the number of clicks through automation and enables advanced visualization of multi-parametric data with ease.

Advanced Radiology Imaging Center performs the highest number of breast MR exams within the practice, averaging 75-80 exams plus another 16 MR breast biopsies each month, Mushinsky adds.

"The SIGNA™ Voyager now allows us to accommodate the bariatric patient for either a routine breast MR and/or MR breast biopsy. In the past, we had to refer them to another RadNet site with a wide bore, which often was not the most convenient for the patient."

Apart from the comfort and convenience of providing breast MR at Advanced Radiology Imaging Center, Mushinsky says the patients are astounded when the exam is completed in less time than ever before. "They are on and off the table quickly and leave with a smile on their face."

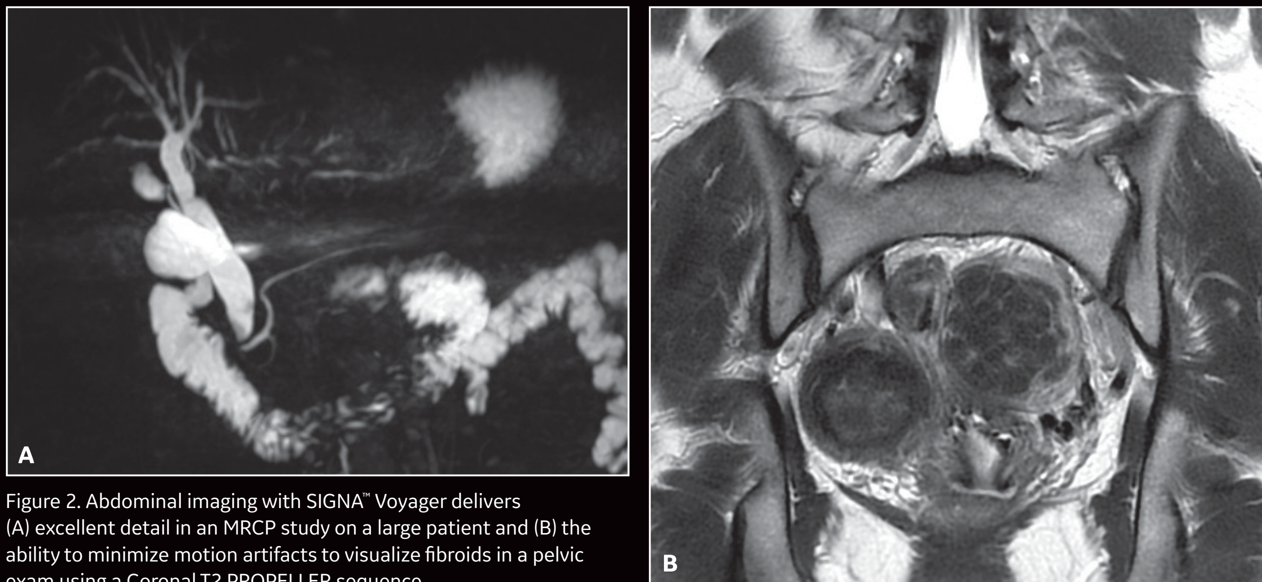


Figure 2. Abdominal imaging with SIGNA™ Voyager delivers (A) excellent detail in an MRCP study on a large patient and (B) the ability to minimize motion artifacts to visualize fibroids in a pelvic exam using a Coronal T2 PROPELLER sequence.

With the increased efficiency, appointment times for breast MR exams are now in line with all the routine exams they perform at 30-minute slots. This has opened up the ability to add additional breast MR patients to an already packed schedule.

SIGNA™ Voyager also provides free-breathing, motion-free and needle-free applications. Auto Navigator, compatible with Turbo LAVA, Turbo LAVA Flex and DISCO, enable complete body exams without a single breath-hold. Advanced 3D motion correction technology, such as 3D PROMO for neuro imaging and PROPELLER for head-to-toe 2D motion correction, helps eliminate the need for patients to lie motionless throughout the scan, making scanning less stressful for the patients. Needle-free imaging capabilities enable non-contrast MR exams that eliminate the pain of needles and the cost of contrast. Whether it's routine MR angiography studies with Inhance 2.0 Suite, advanced imaging such as liver fat-fraction mapping with IDEAL IQ or brain perfusion imaging with 3D ASL, SIGNA™ Voyager enables complete non-contrast MR exams.

A focus on patient comfort and satisfaction are critical to the RadNet mission and a key reason for selecting SIGNA™ Voyager. The organization will typically replace a 60 cm MR with a 70 cm bore rather than upgrade the system in place as a result of feedback from patient-focused surveys detailing substantially increased overall patient satisfaction and comfort.

"That's a key part of our mission: to be more patient centric by providing a larger bore size, concise scan experiences and an inviting, pleasant environment," he adds. "We are committed to providing access to MR for all patients, whether they are larger sized, claustrophobic or have MR-Conditional implants."

RadNet has widely deployed the power of GE Healthcare's compressed sensing technique, HyperSense. HyperSense enables both faster imaging without the penalty typically associated with conventional parallel imaging along with higher spatial resolution images in practical scan times. The impact on patient comfort is significant, says Dr. Tanenbaum.

> "Scan times that are 20 to 30 percent shorter and maintain image quality really increase the value of our MR studies. There is often less patient motion and a higher quality exam, facilitating diagnosis and interpretation. The more efficient and consumer-friendly experience gets patients back to their work or family sooner." S

Dr. Lawrence Tanenbaum

Ben Kelley, MBBS, FAANMS, ANZAPNM
X Radiology Australia, Brisbane, Australia

Dru Morris
X Radiology Australia, Brisbane, Australia

High-end MSK imaging delivers a winning record for X Radiology

In many regards, Brisbane, Australia is a city teeming with professional sport teams and players—from rugby to Australian football to cricket, and more. Most recently, the city was the host of the 2017 Rugby League World Cup and home to several leading rugby teams, such as the Queensland Maroons, Brisbane Broncos and St. George Queensland Reds.

In fact, the St. George Queensland Reds rely on X Radiology Australia, a healthcare facility led by Ben Kelley, MBBS, FAANMS, ANZAPNM and Timothy Demetriades, MBBS, FRANZCR, ANZAPNM. Dr. Kelley and Dr. Demetriades are trained in both radiology and nuclear medicine, and Dr. Kelley is the current honorary match-day radiologist for the Queensland Reds, Wallabies, Super Rugby and all international rugby teams playing in Brisbane.

X Radiology offers an array of imaging services—MR, CT, ultrasound, nuclear medicine and even interventional services. While there is a broad mix of cases, the majority of MR imaging studies performed are high-end MSK. To fill this clinical need, the clinic relies on SIGNA™ Pioneer, an advanced 3.0T scanner.

With the high volume of professional athletes, Dr. Kelley felt that 3.0T was the right investment for the clinic. While several different manufacturers were considered, the stand-out choice was GE Healthcare. With a patient base comprised of many professional athletes, exceptional image quality was top on Dr. Kelley's list of features.

Dr. Kelley also relied heavily on the opinion and expertise of his Lead MR Technologist, Dru Morris. As a premier MR technologist in Australia, Morris was empowered by Dr. Kelley and Dr. Demetriades to recommend the system that he thought best delivered the workflow, sequences and quality imaging that would best benefit patients.

> "The most important reason we chose GE Healthcare and 3.0T was resolution and image quality. We found the SIGNA™ Pioneer had excellent SNR and resolution, and we were confident it would enable us to provide the best imaging possible."
>
> *Dr. Ben Kelley*

Advanced apps

"The SIGNA™Works series of upgrades gave us increased image quality over our previous MR scanner without sacrificing speed," Morris adds. He noted that features such as Flexible

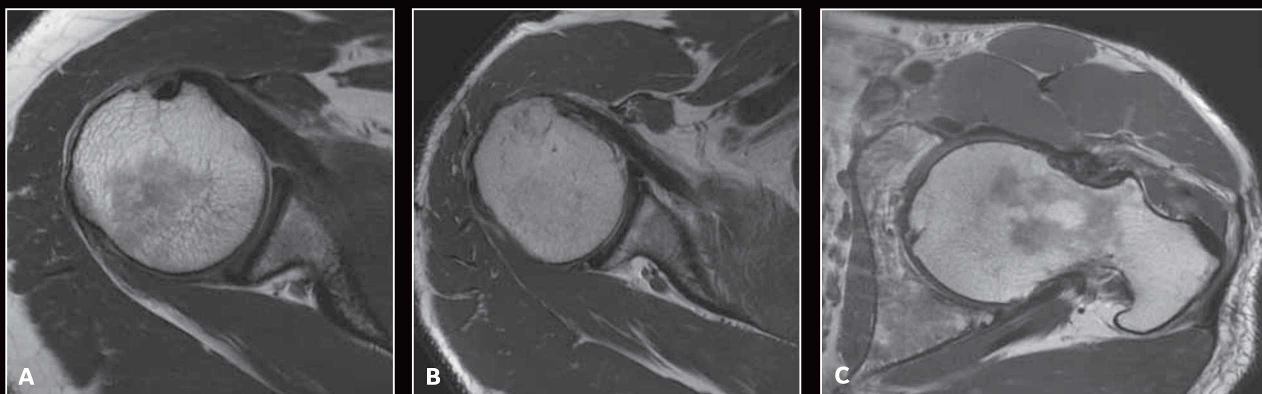


Figure 1. Smaller FOV imaging becomes easier with Flexible No Phase Wrap and the ability to balance SNR vs. scan time; (A) Flexible No Phase Wrap, 3 x 0.3 x 0.3 and 10 cm FOV compared to (B) Legacy No Phase Wrap 3 x 0.3 x 0.5 and 15 cm FOV. (C) Flexible No Phase Wrap with a small FOV in the hip, 3 x 0.5 x 0.5 and 15 cm FOV, 1 NEX, scan time of 3:01 min.

No Phase Wrap delivers speed and image quality while allowing adjustments based on different body habitus. Morris said he can adjust the scan for larger-sized patients, such as professional rugby or football athletes, without losing scan time.

"Flexible No Phase Wrap has made an amazing impact in the SNR," Morris says.

HyperSense and FSE Flex were two other sequences that Dr. Kelley felt were must-haves for his clinic.

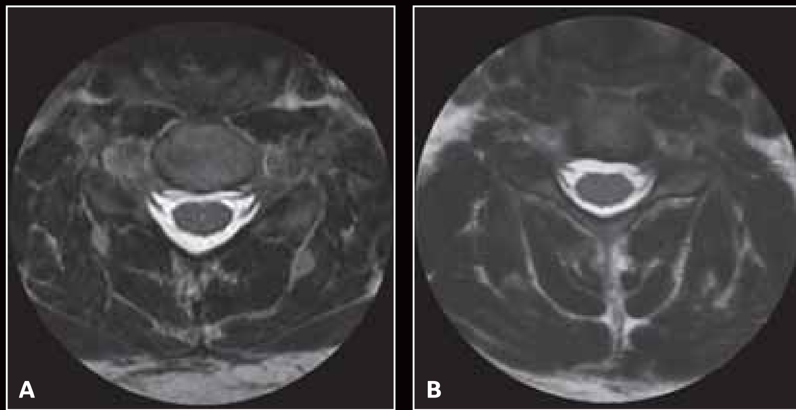
"The primary benefit of HyperSense is the reduction in scan time without any noticeable deficit in image quality," says Dr. Kelley. "It's a good tool that we use whenever we can."

Although the clinic has not adjusted its schedule to accommodate more patients with the reduction in scan times, having more time is a luxury that both Morris and Dr. Kelley appreciate. The top priority at X Radiology is quality. By utilizing HyperSense to reduce scan times, Morris has the option to include additional sequences for a more comprehensive exam. For example, Morris will use HyperCube in neuro imaging studies to increase diagnostic confidence for the reading radiologist.

In particular, Morris adds that the Sagittal HyperCube FLAIR in the brain delivers the images the radiologists rely upon for a more confident diagnosis. While the majority of MSK exams are performed with 2D sequences, most neuro exams are now acquired with 3D imaging.

"We will use the Axial T2 as a roadmap but the thin-slice IR and in-slice 3D is where we get that increase in diagnostic confidence. That confidence comes from the ability to page through each slice—almost using a CT approach to MR imaging—with high-resolution images that don't suffer from signal drop out."

Dr. Ben Kelley



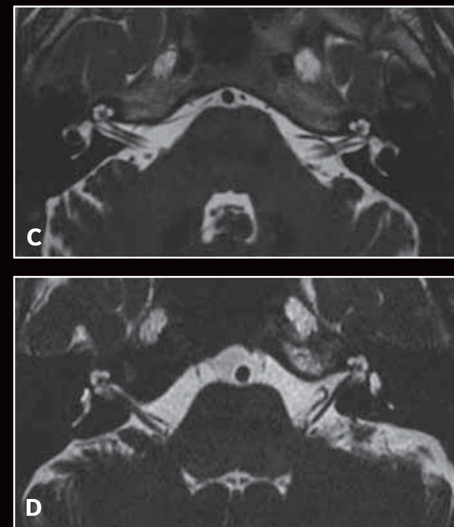


Figure 2. Combining Flexible No Phase Wrap with HyperSense can further reduce scan times while maintaining spatial resolution. (A) Conventional scan at 3:16 min. (B) Flexible No Phase Wrap with HyperSense factor of 1.8 in a scan time of 2:40 min. (C) Conventional scan in 2:27 min. (D) Flexible No Phase Wrap with HyperSense factor of 1.8 in scan time of 1:43 min.

Figure 3. Cube T2 FLAIR with HyperSense. With one volume/plane acquisition, the user can reformat in multiple planes. Thin slices with no gap can increase diagnostic confidence. Sequence acquired in 4:16 min. (A) and (B) are reformatted from (C).

Making the scanner sing

As a long-time user of leading MR technology across the region, Morris has learned to optimize complex scanning techniques. Yet, the patient always comes first.

If the patient is happy after the scan, and the radiologist has the information they need for diagnosis, then it's a win all around.

> "Patient comfort is very important for us. If we can get the patient comfortable and not moving, then the overall scan time is quicker and more efficient in the resolution we require for high-quality images."
>
> *Dru Morris*

Simplified patient setup and scanning is one way Morris can tighten up his workflow for more efficient scanning. For example, with SIGNA™ Pioneer he has intuitive, IntelliTouch landmarking, which means he can landmark on the fly and doesn't have to perform this on the scanner. The dual touchscreen displays also make it easy to perform in-room setup of the scan.

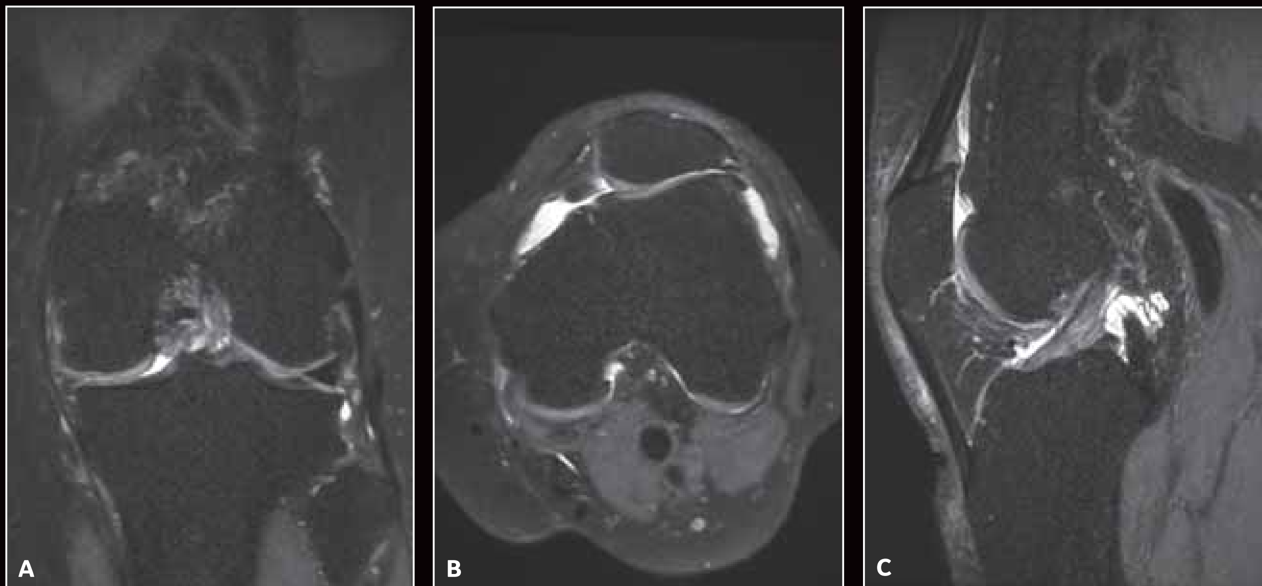


Figure 4. MSK knee exam using 3D Cube with FatSat and HyperSense in a scan time of 4:08 min.

Plus, Auto Protocol Optimization utilizes an intelligent algorithm to automatically adapt the protocol to varying patient profiles. Morris simply selects from several options; this tool helps him avoid variance in image quality and exam times.

"The system recalculates based on the patient's size," Morris explains. Based on the scan parameters and patient habitus, the optimization tool automatically adjusts the actual pixel size and resolution so that Morris can ensure the spatial resolution is maintained throughout the exam.

"It really comes back to no weaknesses in this MR system and providing our staff with the right equipment, hardware, software and product support," says Dr. Kelley.

Another advantage is the opportunity to invest in upgradeability. Dr. Kelley views the SIGNA™ Lift and SIGNA™Works programs as opportunities for his practice to evolve and continue to deliver the best in MR imaging both today and tomorrow.

"With every new technology that comes through from GE, we can look at it and apply it to this platform. That ability to stay ahead of the curve and not have any weaknesses because the system is upgradeable and supported by the company means there are no black holes."

Dr. Ben Kelley

"I sometimes report scans at the professional games," Dr. Kelley adds. "It is good to have confidence that you are getting a premium quality scan."

At X Radiology, whether it's the advanced MR technology, the friendly staff, the expert radiologists or the inviting and modern facility, it truly is all about the patient experience.

"We are only as good as our weakest link, and with SIGNA™ Pioneer, from the hardware to the software to the focus on patient comfort, there are no weaknesses," Dr. Kelley says.

Rhys Slough
Cambridge University Hospital,
Cambridge, England

Using big data to improve operational efficiency & clinical excellence

As the range and complexity of MR imaging continues to evolve, it brings challenges for the efficient operation of an MR imaging service. While many imaging providers primarily focus on adopting new techniques to obtain the highest quality imaging, they generally do not quantify the impact on operational efficiency. The information is available but hidden in the headers of the images, e.g., protocol name, examination duration and the time between examinations. Many imaging departments are managing operations without insight into the impact that even the smallest changes in technology and staffing may have on productivity and profitability.

Recognizing this need, GE Healthcare has developed a new program, MR Excellence, that is a combination of digital analytics and customer success services to help improve clinical excellence and operational efficiency. The analytics solution, called Imaging Insights, provides a full fleet (multi-vendor, multi-modality) practice summary of utilization, clinical protocol, patient experience and referral metrics that enables radiology directors, imaging supervisors and clinicians to optimize clinical and operational performance of their imaging assets.

Through regular and sustained touchpoints, customer success services leverage clinical experts, educational material, and technical support to help the customer achieve clinical and operational efficiency.

Cambridge University Hospital (CUH) is one of the first sites working with MR Excellence. CUH is one of the largest and best known hospitals in the UK, representing a local hospital for the community, a comprehensive biomedical research center, major teaching hospital and one of six UK academic health science centers. Its MR department currently hosts six GE MR systems (three Optima™ MR450w, one

Figure 1. Information from the MR Excellence program helps Slough manage six MR systems in his department.

Optima™ MR450, one Discovery™ MR750 and one mobile SIGNA™ Explorer). Rhys Slough, MRI Manager, expects 32,000 inpatient and outpatient MR exams in 2018, representing a nine percent sustained growth year after year. He has been involved with the implementation and evaluation of MR Excellence—and the power of the information it collects.

"I'm really impressed by MR Excellence," he says. "The drive to greater operational efficiency needs this kind of data monitoring and analytics. Today, it's all about working smarter and more efficiently. We should all be looking to challenge the attitudes and behaviors of yesterday to ensure our patients receive the care they deserve today."

Slough sees potential for the program beyond MR, but for now he's focused on the impact of how data analytics can help him make the right clinical scanning and operational decisions for both patients and staff.

Excellence uncovered

Slough has competing interests in the management of a six system MR imaging department; on one side is clinical excellence; on the other is operational efficiency.

"There is some overlap between clinical and operational as it relates to acquisition times," Slough explains. "Quality costs time, and time is the enemy of throughput. So, it requires a balance."

In the first month of using MR Excellence, Slough determined the department had nearly 300 variations of protocols across six MR systems, a number that was larger than expected.

"We've had MR for over 30 years and have had over 13 systems in this time," he explains. "New protocols would be added with the addition of extra sequences or set ups without removing the original or basic sequence. We found a lot of duplication in protocols, especially for the neuro axis, MSK and hepatobiliary work."

For example, a lumbar spine would have protocols for feet first or head first. Or, the addition of a new coil, for example a 32-channel body coil, would lead to new protocols such as a 32-channel MRCP. With three different body coils, this process led to 20 different protocols for body imaging.

Slough explains, "Whilst this might add 'efficiency' for some radiographers, it removes it for others. It also leaves sequences contained within some protocols at risk of being 'left behind' as improvements are made elsewhere but not carried throughout the fleet of systems."

There was also room for improvement in the technologists' workflow. He could identify variations in staff performance within and between rooms, including patient turnaround times (TAT). MR Excellence confirmed the anecdotal evidence that the 3.0T system or other 1.5T systems that had multiple and/or more experienced staff had faster TATs. TAT is the department's greatest variable, Slough says, and

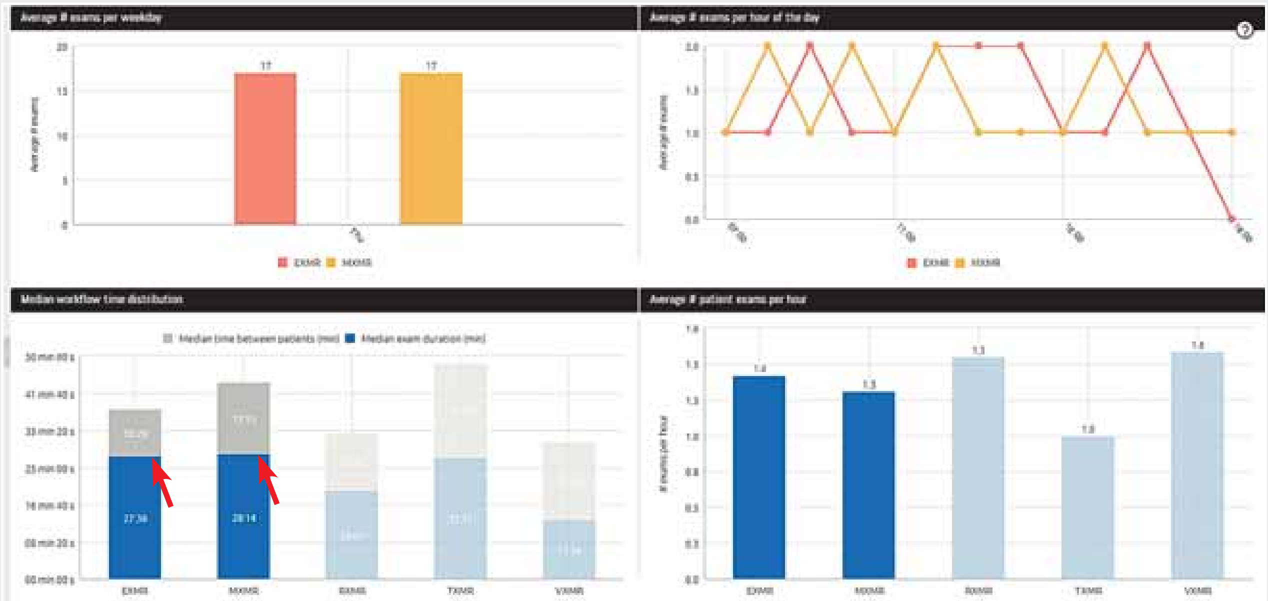


Figure 2. Same number of patients between the two rooms, but the time in between patients is 5 minutes greater, on average, for the MXMR room. Across a 13-hour day with approximately 20-24 patients, the discrepancy is ~100 minutes (1:40 hours) of wasted magnet time versus another magnet.

with the information in MR Excellence he can see how long it takes each MR system and staff combination to scan and turnaround patients.

"MR Excellence gives me an average, minimum and maximum range of performance for the department as well as the subtler variations across the systems," Slough explains, "These variations can often lead to staff dissatisfaction and unnecessary stress. We want to avoid the peaks and troughs throughout the day that indicate faster and slower TATs, and strive to achieve a consistent standard and pace throughout the working day."

For example, Slough could see that TAT decreases during the lunch-time period, then increases again after lunch when the full staff returns. There are also slowdowns in the mid-afternoon and then speed-ups again near the end of the day.

He could also address issues, such as one system running slower and another system having to then scan additional patients. With the data from MR Excellence, Slough determined that the slower system was taking five minutes longer for each patient TAT.

"Five minutes across 13 hours is 100 minutes. That's two to three appointments each day," Slough says. "When this happens across six systems, the impact becomes significant."

As an example, Rhys together with the neuroradiologists changed the contrast-enhanced MR brain protocol, by incorporating the latest features in the SIGNA™Works DV26.0 software release with the objective of ensuring the total examination time did not exceed 30 minutes. However, staff were unable to deliver this immediately and became frustrated at the change.

Slough explains, "MR Excellence was able to show the staff that the failure to meet this target was most often due to slower TATs rather than the new protocol. Periodic review allowed new staff to monitor their progress and improve TATs, which in turn led to better staff satisfaction. Once staff had seen that others can achieve it, we were able to work as a group and identify improvements across the team."

By examining TATs, Slough can also determine when a particular exam falls outside his 85/15 ratio: 85 percent of the appointment is MR acquisition time and 15 percent is patient TAT. He can use the information to support additional technologist training and development where needed.

"Now I can deliver focused training, review a protocol or review that day's scheduling," Slough adds. "As a team, we can work together to make improvements and that boosts the whole team's confidence."

Acquisition parameters of original series

Series description	Study protocol name	Device	# exams	Median serie's duration (min)	Standard deviation (min)
Ax T2 FRFSE NAV	ADH_Liver (Gadovist)	EXMR	14	05 min 02 s	01 min 30 s

Series description	Study protocol name	Device	Median slice thickness (mm)	Median repetition time	Median # excitation	Median frequency matrix	Median phase matrix	Median field of view (mm)	Median percent phase field of view	Mediar accelerati factor
Ax T2 FRFSE NAV	ADH_Liver (Gadovist)	EXMR	8.0	5,000.0	4.0	320.0	256.0	360.0	70.0	1.0

Acquisition parameters of original series

Series description	Study protocol name	Device	# exams	Median serie's duration (min)	Standard deviation (min)
Ax T2 PROPELLER NAV FS	ADH_Liver (Gadovist) UPD	EXMR	18	04 min 30 s	01 min 52 s

Series description	Study protocol name	Device	Median slice thickness (mm)	Median repetition time	Median # excitation	Median frequency matrix	Median phase matrix	Median field of view (mm)	Median percent phase field of view
Ax T2 PROPELLER NAV FS	ADH_Liver (Gadovist) UPD	EXMR	6.0	15,000.0	2.0	288.0	288.0	420.0	100.0

Figure 3. Comparison of the old navigated Axial T2 frFSE versus the new protocol for navigated T2 PROPELLER Liver.

The data also helps Slough oversee improvements to the body imaging protocols. With the DV26.0 upgrade, the team wanted to change the DWI liver protocol from a breath-hold to a respiratory navigated sequence. The sequence took advantage of thinner slices and higher resolution but at the expense of additional scan time.

"Navigated DWI is absolutely brilliant," says Slough. "It helps our radiologists see the small metastases in the hepatobiliary system and other abdominal organs, which is where the sequence is really changing patient care. This new information is better guiding our transplant surgeons in making significant surgical care decisions with confidence. This is where I can confidently say it is worth the additional five minutes for a better outcome. I can then strive to recover that five minutes from elsewhere in the day. In an era of patient-centered care, this is the approach we must bring to our imaging."

A further example of using MR Excellence to assess the introduction of a new sequence is with the navigated PROPELLER in DV26.0. By analyzing the median time and standard deviation between the longest and shortest scan times for the existing sequence, a navigated Axial T2 frFSE, Slough and the radiologists could determine that moving to the PROPELLER sequence did not incur any additional time.

"The benefit of navigated PROPELLER is a much higher resolution, thinner slice sequence with far superior motion robustness. That is a big win for image quality without impacting time," Slough explains. "I can provide this information back to the radiologists and quantitatively demonstrate that it was a good decision to change sequences and confirm that it isn't taking any more time."

Overall, MR Excellence helps Slough and his team run a more efficient department. It helps him maintain protocols, decide where and when to add new sequences, reduce variability in radiologist-specific protocols and quantify the impact of clinical decisions.

He adds, "If you want comprehensive data analytics for your department, this is an ideal tool, not just for MR but potentially for all of imaging." S

James Sancrant, DO
Triad Radiology Associates,
Novant Health Imaging Maplewood,
Winston Salem, North Carolina

Fast & affordable 10-minute breast MR exam

James Sancrant, DO, a radiologist at Triad Radiology Associates in Winston Salem, North Carolina, convinced his health system to implement an abbreviated breast MR exam. Now he's able to scan patients in 10 minutes or under and provide affordable breast MR imaging services to patients.

In 2014, North Carolina became the 12th state to require all facilities that perform mammograms to notify patients if they have dense breast tissue. The legislation included language that encourages women to discuss other screening options with their care providers. Although Dr. Sancrant embraced the new law, he felt it didn't go far enough. "They said women should talk to their doctor about supplemental screening, but there was no guidance for supplementing screening mammography," he says. "That's where we felt abbreviated breast MR could help."

In May 2015, Dr. Sancrant spearheaded the implementation of an abbreviated breast MR exam that scans patients in 10 minutes or less and costs significantly less than a traditional breast MR exam. Novant Health offers both full and abbreviated breast MR exams, but only the full exam is covered by insurance. However, many women are faced with high deductibles and

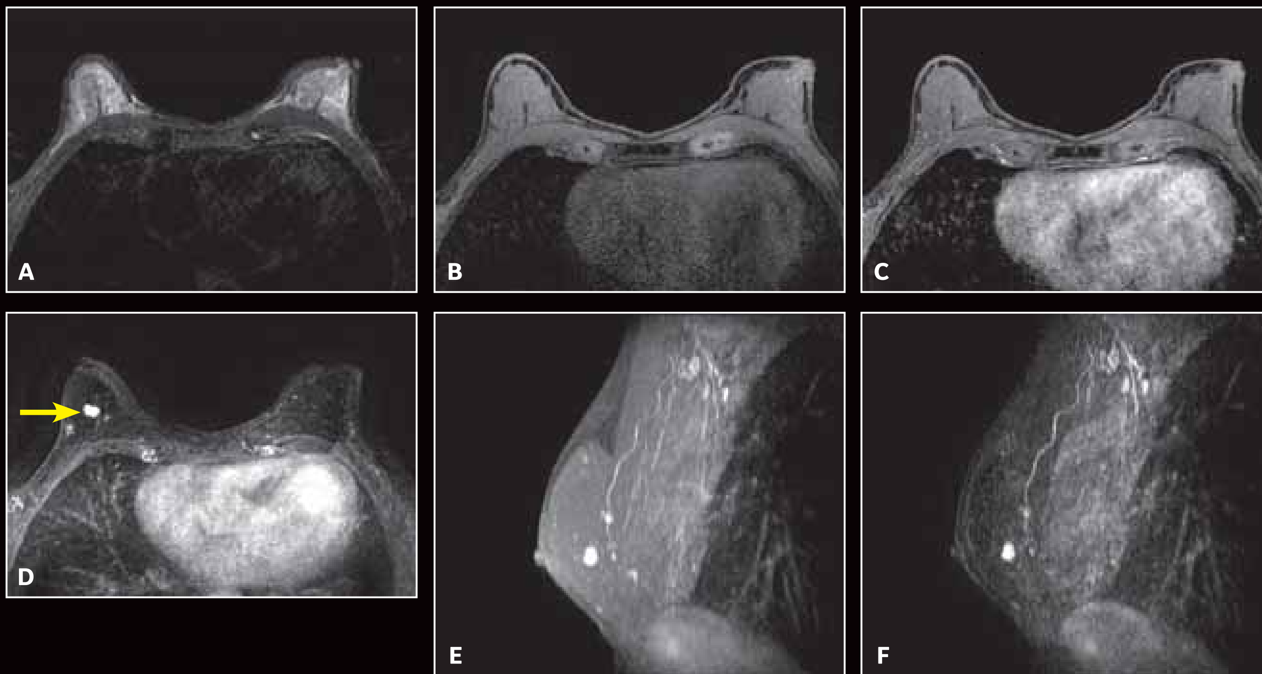


Figure 1. (A) Axial FSE T2 FatSat pre-contrast, (B) Axial VIBRANT T1 FatSat pre-contrast, (C) Axial VIBRANT T1 post-contrast, (D) Axial dynamic subtracted, (E) Sagittal reformat of the T1 post-contrast and (F) Sagittal reformat of the dynamic subtracted. Note the 1 cm enhancing lesion confirmed by pathology as invasive ductal carcinoma.

co-pays for health services, leaving them with a large share of the cost. This motivated Dr. Sancrant to offer the abbreviated exam.

In the US, the cost of a breast MR exam may not be fully covered by insurance. As a result, many women incur additional costs for the exam. "MR time is very expensive. To convince a healthcare facility or health system to do this at such a small cost, it has to be fast," he says.

Novant Health was able to offer the exam for just $399, complete with contrast, the MR exam itself and reading by a radiologist. It is, however, an out-of-pocket, cash-only fee. Novant also put aside money for women who are financially not able to pay the fee.

"There's nothing more expensive than a missed cancer or a false negative," says Dr. Sancrant.

In late 2016, the facility installed the SIGNA™ Pioneer, Sancrant's preferred system for the abbreviated breast MR exam.

"The spatial resolution on the SIGNA™ Pioneer is exceptional," he says. "Qualitatively, we can now offer a truly powerful exam. When you explain to patients that a screening mammogram can miss a lot of cancers in dense tissue, they are anxious and disappointed in that study. But when we tell them we have an option with MR, and I show what we can do once we remove the background tissue, they are in awe," he says.

In several cases, traditional screening mammography didn't detect invasive breast cancer, but the abbreviated breast MR exam did. "The most important thing is that the abbreviated MR exam detected breast cancers that would not have been detected and would have presented at a later stage with a poorer prognosis."

Inspired by research

Dr. Sancrant learned about the abbreviated breast MR exam through a study he read in the *Journal of Clinical Oncology*.[1] The study, by Dr. Christiane Kuhl from the University of Aachen in Germany, reported the results of comparing the performance of abbreviated MR exams to traditional mammography, as well as a full unabridged MR of the breast.

> "The published data shows that the current specificity of MR is on par with screening mammography, but with much better sensitivity. So, it's as good as mammography, but more sensitive."
>
> *Dr. James Sancrant*

It reviewed exams from asymptomatic women with heterogeneously dense breast tissue, a patient population that often experiences challenges with traditional screening methods.

The study showed a detection rate of 18 breast cancers in 1,000 women – versus four breast cancers with standard analog screening and five with additional ultrasound screening.

"It was staggering and profound, but also somewhat intuitive to those of us with experience in MR breast imaging," says Dr. Sancrant. "We know that we can see through dense breast tissue as though it's not there. MR just doesn't depend on the physical characteristics of breast tissue, nor is it impaired by the density of breast tissue that X-rays are attenuated by."

The abbreviated breast MR sequence he uses was also inspired by Dr. Kuhl. It includes a VIBRANT Axial T1 FatSat, a pre-contrast Axial T2 FatSat and a VIBRANT Axial T1 FatSat post-contrast. The images are post-processed for a subtraction and a maximum intensity projection (MIP) view. Dr. Sancrant and his colleagues also experimented using other sequences, including a second delayed T1 post-contrast to have two time points.

In the post-processed data, the most important are the subtraction images, followed by the MIP. He notes this sequence also reduces the reading time. "It is extremely fast to look at those two sequences. If they are negative, then there's no need to look at the other sequences. If there's something there, then you can correlate with T2."

"We mimicked what Dr. Kuhl did. For years, we relied heavily on the immediate T1 Axial post-contrast as our key acquisition for diagnosis. Breast cancer enhances early compared to tissue; Dr. Kuhl's article underscored that and our experience further demonstrated this."

Dr. James Sancrant

5 sequences in under 10 minutes

Sequence	Time (min.)
FSE T2 FatSat Axial pre-contrast:	2:27
VIBRANT T1 FatSat Axial pre-contrast:	1:22
VIBRANT T1 FatSat Axial post-contrast:	1:22
Post-processed subtraction post-contrast Axial:	Auto subtracted by the scanner
Post-processed subtraction post-contrast MIP:	Auto subtracted by the scanner

Parameters	*Axial T2 FatSat*	*Axial Dynamic Pre-/post-contrast*
TR:	6872	5.3
TE:	101/Ef	2.1
EC:	1/1, 83.3 kHz	1/1, 83.3 kHz
TI:		24
ET:	15	
Scan time:	2:31 min	1:20 min
NEX:	2	0.7
Matrix:	320 x 320	360 x 360
DFOV:	32.0 x 32.0	32.0 x 32.0

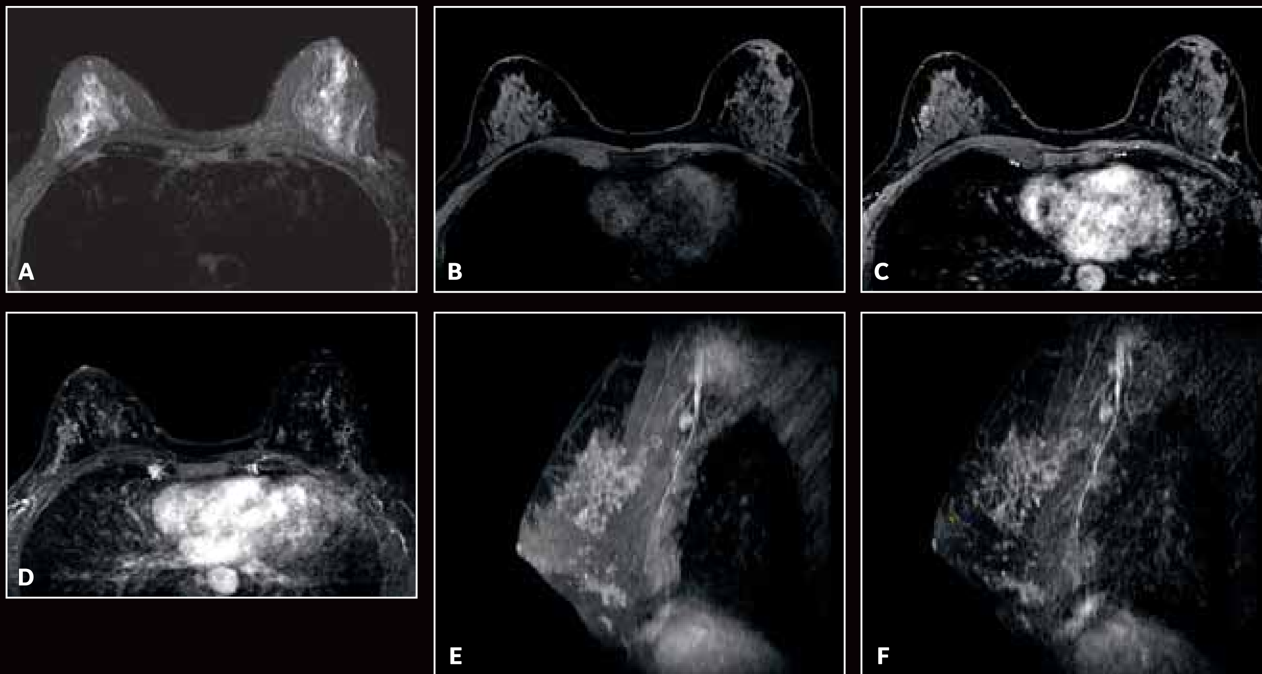


Figure 2. (A) Axial FSE T2 FatSat pre-contrast, (B) Axial VIBRANT T1 FatSat pre-contrast, (C) Axial VIBRANT T1 post-contrast, (D) Axial dynamic subtracted, (E) Sagittal reformat of the T1 post-contrast and (F) Sagittal reformat of the dynamic subtracted.

Good for physicians, good for patients

The abbreviated exam is appealing to patients because it's shorter and therefore less anxiety-inducing, plus it's more affordable. "It's changed the outcome in a few patients who just wouldn't have had a standard breast MR because of financial barriers," he says.

Dr. Sancrant encourages radiologists who are considering implementing an abbreviated breast MR exam to start reading standard breast MR cases as an abbreviated study. "Only look at those sequences that are available with an abbreviated breast MR. Get comfortable with it before you start offering abbreviated breast MR. I'm confident that if you do it carefully and test yourself, you'll find that it performs extremely well."

Overall, Dr. Sancrant feels an abbreviated breast MR study delivers the quality care his patients need. "We strongly believe that it's in the best interest for patients to offer this to women who have dense breast tissue."

Women with dense breasts often receive a lot of call backs, which leads to additional tests and/or biopsies. That uncertainty is removed with MR imaging.

> "With breast MR, we can disregard it if it's negative, and that saves on costs, from co-pays and deductibles to more money spent on call backs and biopsies."
>
> *Dr. James Sancrant*

His facility is now in a multi-site ACRIN study with principal investigator Dr. Christopher Comstock comparing the abbreviated breast MR to digital breast tomosynthesis in asymptomatic women with dense breasts.[2] He hopes this study will show the health—and financial—benefits of an abbreviated breast MR study.

"At the end of my career, when I look back and retire, I think abbreviated breast MR will have had the most profound impact on saving additional lives from breast cancer," he says.

References

1. Kuhl CK, Schrading S, Strobel K, Schild HH, Hilgers RF, Bieling HB. Abbreviated Breast Magnetic Resonance Imaging (MRI): First Postcontrast Subtracted Images and Maximum-Intensity Projection—A Novel Approach to Breast Cancer Screening With MRI, J Clin Oncol. 2014 Aug 1; 32(22):2304-10.
2. Abbreviated Breast MRI and Digital Tomosynthesis Mammography in Screening Women With Dense Breasts. ClinicalTrials.gov Identifier: NCT02933489. Available at: https://clinicaltrials.gov/ct2/show/NCT02933489.

Multi-parametric imaging in shorter scan times for prostate cancer imaging

By Professor Fatih Kantarci, MD, Head of the Radiology Department, Surp Pirgic Armenian Hospital, Istanbul, Turkey

Prostate cancer is the second most common cancer in men worldwide.[1] The emergence of the prostate-specific antigen (PSA) test has been credited with a reduction in prostate cancer-related deaths due to its efficacy in detecting both aggressive and slow growing tumors. Clinicians now heavily rely on this test in practice. However, it has led to the overdiagnosis of clinically insignificant cancers that in many cases would not have resulted in death. Selection of patients for active surveillance has led to 20-30 percent misclassification rates.[2]

Active surveillance is often employed for patient management of these clinically insignificant, or indolent, prostate cancers. However, an accurate diagnosis is essential as it directly impacts treatment choice and follow-up.

In addition to its use as a diagnostic tool to localize and characterize prostate cancer, MR imaging has emerged as a useful tool for the active surveillance of prostate cancer. Multi-parametric MR imaging may help minimize invasive follow-up. Positive MR findings that are concordant with the initial biopsy have a low reclassification rate.[2]

Common challenges to MR imaging of the prostate include gland size variations from patient to patient, depending on tumor size, as well as an enlargement of the gland due to benign prostatic hyperplasia, the existence of benign lesions and the multi-focal nature of cancer. Additionally, the patient must be properly prepped. A liquid diet and laxative support may help to eliminate gas and fecal content in the imaging area.

When imaging the prostate, high spatial resolution is necessary due to the small region of interest. Imaging of the prostate is prone to motion artifacts, both involuntary peristatic and respiratory induced, and therefore scan time reductions and the use of motion insensitive techniques are desired.

Fatih Kantarci, MD
Surp Pirgic Armenian Hospital,
Istanbul, Turkey

A comprehensive prostate workflow

The Surp Pirgic Armenian Hospital is located in the heart of Istanbul. Since 1832, it has been an important healthcare provider throughout the region, offering the latest in technological advancements to provide access to quality care for all patients. In late 2015, we replaced our nine-year-old SIGNA™ Excite 1.5T system with SIGNA™ Pioneer, a 3.0T MR system that included the latest advancements in sequences and coil technology.

Recent advancements in multi-parametric imaging, such as FOCUS DWI and MAGiC DWI, provide high-resolution and high b-value results. FOCUS DWI delivers small FOV, high-resolution images with minimal artifacts in the region of interest. MAGiC DWI provides non-compromised, high b-value imaging with high SNR and allows us to adjust DWI contrast in post-processing. With MAGiC DWI, we can synthesize the contrast from higher b-values with shorter scan time and increase SNR from lower b-value scan times.

The addition of DISCO enables high spatial and high temporal resolution imaging while PROPELLER MB provides motion reduction and a high contrast-to-noise ratio. We've also experienced a significant reduction in scan times after employing HyperSense and HyperCube on our conventional 3D Cube sequence. These sequences and techniques are all available on the SIGNA™Works application portfolio available on the SIGNA™ Pioneer.

The impact on patient care in our institution after implementing the new system and sequences is compelling. These advancements, along with the use of PROView for reading and reporting prostate exams, have become invaluable for helping determine the appropriate PI-RADS™ V2 category. PROView guides our workflow with prostate volume calculation, PSA density, lesion mapping and measurement. We can score T2-weighted, DWI and dynamic contrast-enhanced acquisitions, localize lesions per guidelines and add newly detected lesions for a more comprehensive report.

By using MR imaging and ultrasound-guided biopsy, we have experienced a significant decrease in the rate of non-diagnostic blind biopsies. With GE Healthcare's Total Digital Imaging coil technology, we noticed dramatic increases in SNR and no longer required the use of an endorectal coil—something our patients appreciate and has led to higher patient cooperation and comfort.

Together, these advancements in patient care enabled by SIGNA™ Pioneer and SIGNA™Works have led to a dramatic increase in volume. With our prior system, we would perform 25-30 exams each year with an endorectal coil. In just the first year after installing SIGNA™ Pioneer, our volume doubled, then doubled again the following year to 100 patients. In just the first five months of 2018 (our third year), we've already performed 100 prostate MR exams and anticipate this service will continue to grow.

> In particular, I am now more confident in distinguishing between PI-RADS™ 3 versus 4 in peripheral zone lesions and identifying clinically non-significant (Gleason 6) lesions that can be actively monitored.

SIGNA™ Pioneer

PARAMETERS	
	3D T2 Cube
FOV:	24/14.4 cm
Matrix:	260 x 260
Thickness:	1/0.5 mm
HyperCube:	60% phase encoding FOV
HyperSense:	1.2
Scan time:	5:15 min.

Case 1

Patient history

A 72-year-old with PSA test results of 7.5 ng/ml and a normal digital rectal examination. PI-RADS™ score was 5 and Gleason score was 4, based on biopsy. Patient was diagnosed with transitional zone anterior prostate cancer. PSMA PET/MR also indicated kidney mass uptake and possible metastases.

Technique

HyperCube was utilized to restrict the region of interest, which helps for managing physiological motion artifacts and overall scan time reduction with unique selective RF pulse technique (Figure 1).

Adding HyperSense with a factor of 1.2 combined with ARC resulted in a total scan time of 5:15 minutes.

Figure 1. T2w images of the prostate using HyperCube with a 60% phase encoding FOV and HyperSense with a factor of 1.2 in addition to using ARC for a scan time of 5:15 min.

SIGNA™ Pioneer

PARAMETERS	
	Axial FOCUS DWI #1
FOV:	26 x 9 cm
Matrix:	160 x 56
Thickness:	3/0.3 mm
No. of slices:	54 (18 x 3)
Scan time:	4:35 min.
b-value:	50, 400, 800
	Axial FOCUS DWI #2
FOV:	26 x 9 cm
Matrix:	160 x 56
Thickness:	3/0, 3 mm
No. of slices:	36 (18 x 2)
Scan time:	4:50 min.
b-value:	50, 1400
	DISCO
FOV:	28 x 24 cm
Matrix:	300 x 200
Thickness:	3.6/-1.80 mm
Temp Res:	6.8 sec.
No. of slices:	2132
Scan time:	4:35 min.

Case 2

Patient history

A 71-year-old with PSA test results of 6.4 ng/ml with digital rectum examination findings at the right prostate lobe. Patient was referred to MR for confirmation of initial diagnosis and to assist with staging.

Technique

To reduce motion artifacts, PROPELLER MB compensates for involuntary pelvic motion, allowing for both high resolution and contrast within a reasonable scan time (Figure 2).

Using FOCUS DWI allows for high-resolution, high b-value imaging and optimized scan times, which can enhance the accuracy of ADC maps (Figure 3). The addition of MAGiC DWI helps save scan time by eliminating the high b-value scan (Figure 4).

DISCO was used for ultra-high temporal and spatial resolution and Gen IQ produced accurate permeability maps. For post-processing, READYView was used for seamless 2D/3D image fusion and PROView was brought in for multi-parametric assessment and PI-RADS™ V2 reporting (Figures 5 and 6).

Results

Patient was diagnosed with adenocarcinoma at the left peripheral zone, which differed from the rectal exam that reported findings at the right lobe. Patient PI-RADS™ score was 4 and Gleason score was 7, based on biopsy.

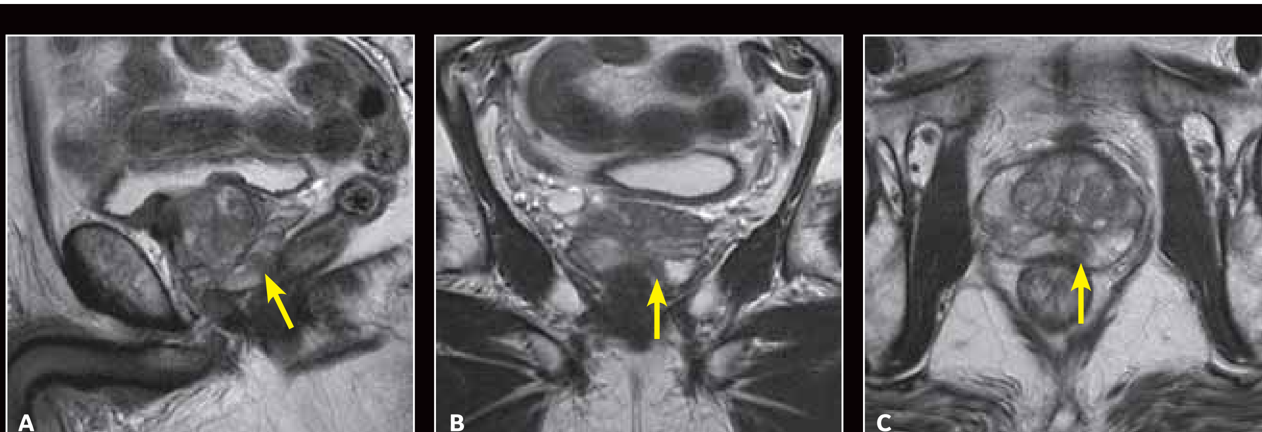


Figure 2. PROPELLER MB compensates involuntary pelvic motion and allows for both high resolution and contrast within a reasonable scan time. (A) Sagittal T2 PROPELLER MB, 20 slices in 2:55 min; Coronal T2 PROPELLER MB, 21 slices in 3:30 min; (C) Axial T2 PROPELLER MB, 26 slices in 3:57 min.

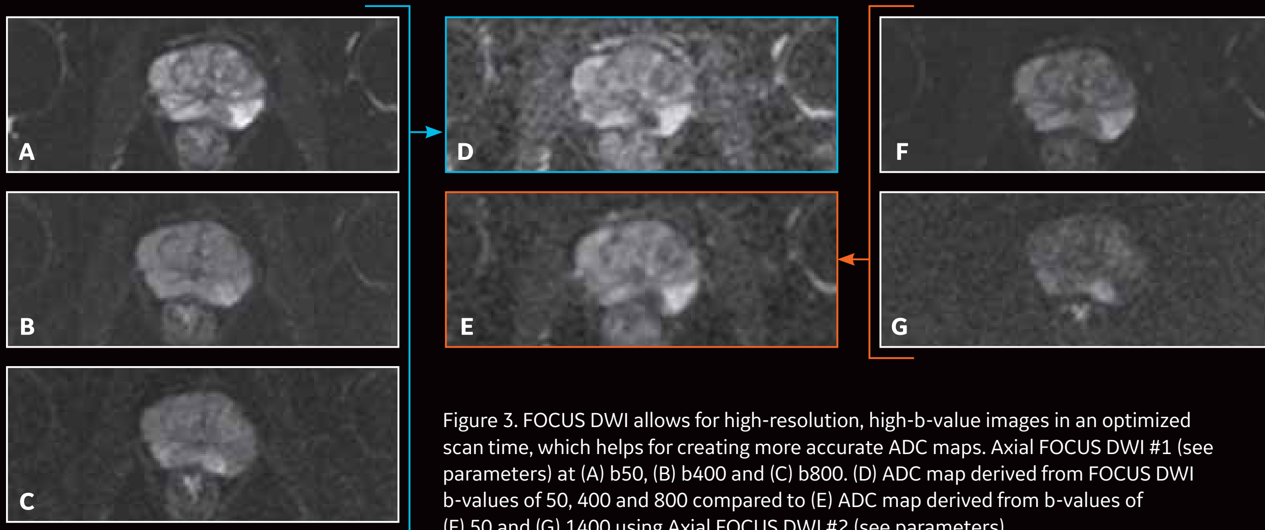


Figure 3. FOCUS DWI allows for high-resolution, high-b-value images in an optimized scan time, which helps for creating more accurate ADC maps. Axial FOCUS DWI #1 (see parameters) at (A) b50, (B) b400 and (C) b800. (D) ADC map derived from FOCUS DWI b-values of 50, 400 and 800 compared to (E) ADC map derived from b-values of (F) 50 and (G) 1400 using Axial FOCUS DWI #2 (see parameters).

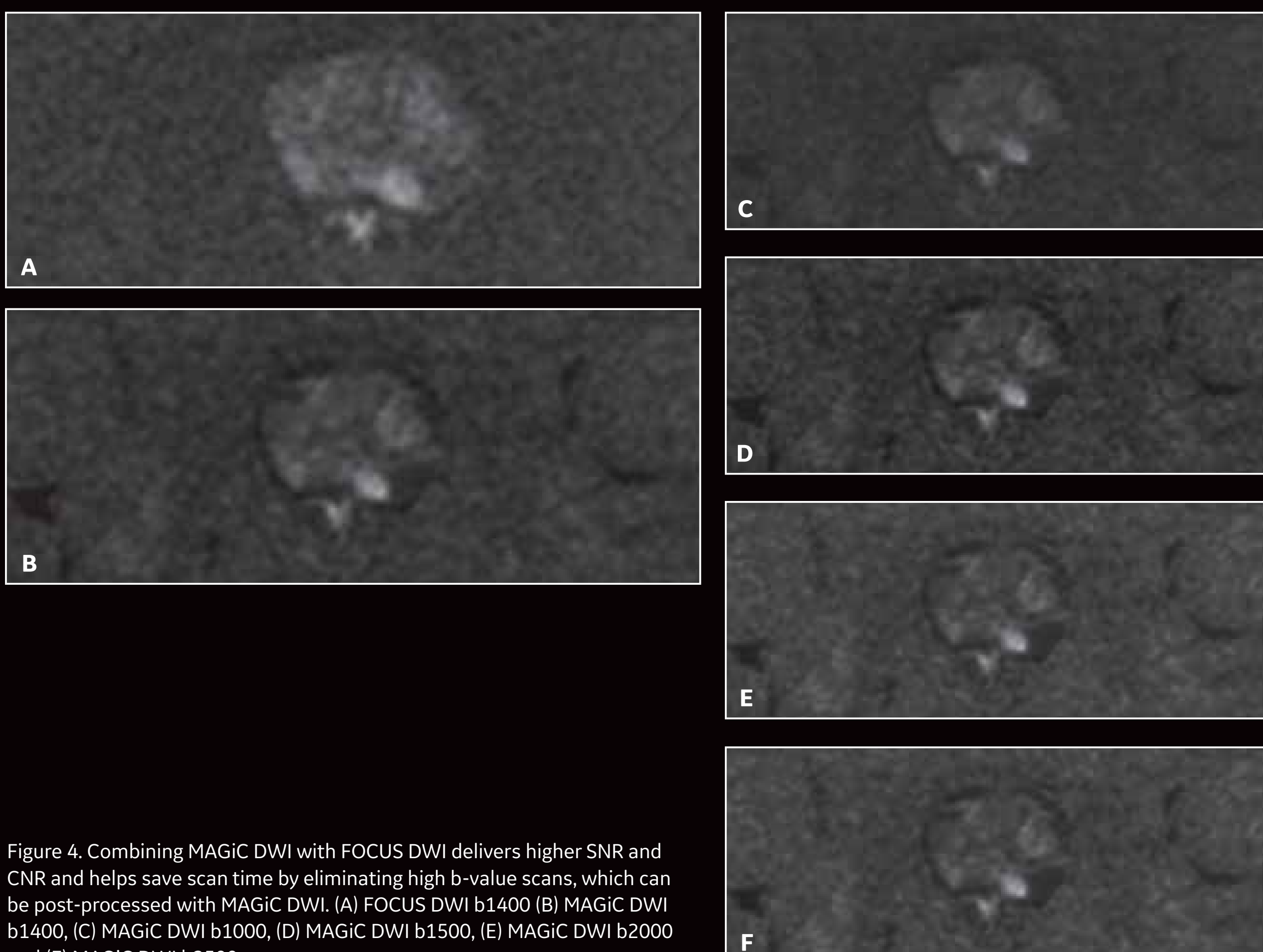


Figure 4. Combining MAGiC DWI with FOCUS DWI delivers higher SNR and CNR and helps save scan time by eliminating high b-value scans, which can be post-processed with MAGiC DWI. (A) FOCUS DWI b1400 (B) MAGiC DWI b1400, (C) MAGiC DWI b1000, (D) MAGiC DWI b1500, (E) MAGiC DWI b2000 and (F) MAGiC DWI b2500.

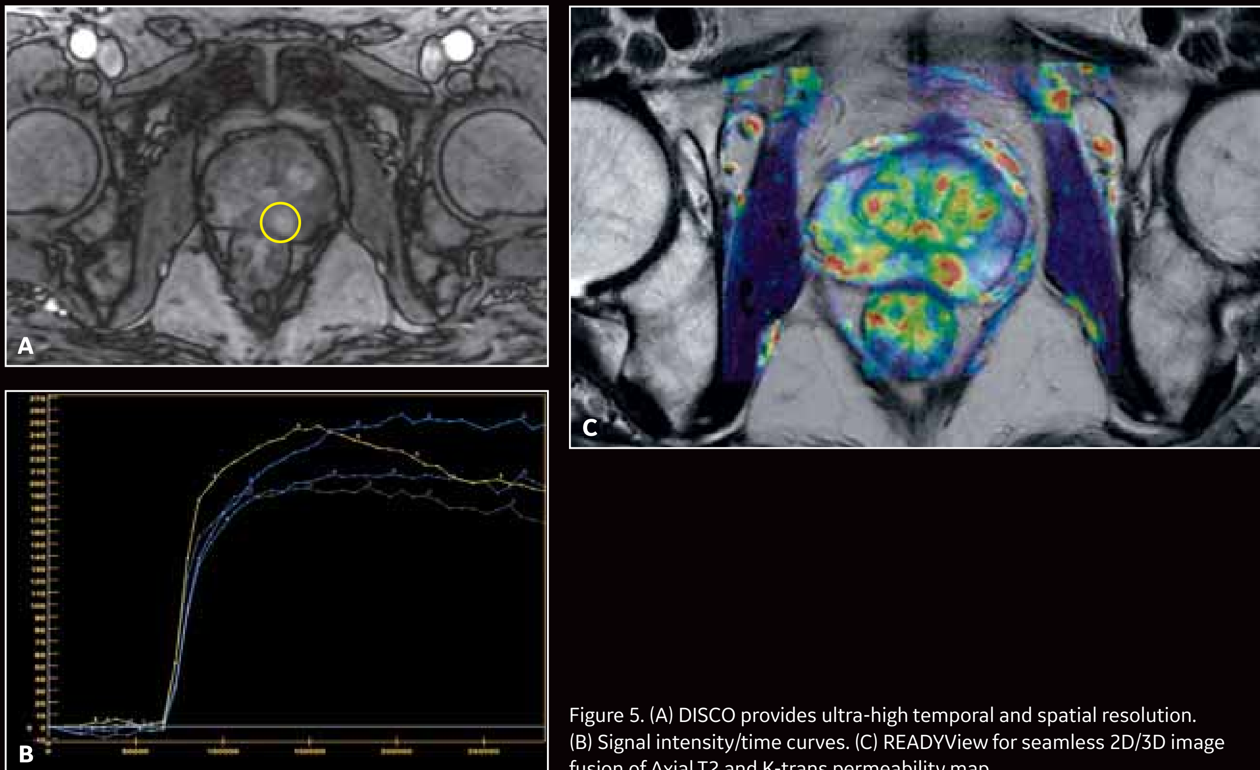


Figure 5. (A) DISCO provides ultra-high temporal and spatial resolution. (B) Signal intensity/time curves. (C) READYView for seamless 2D/3D image fusion of Axial T2 and K-trans permeability map.

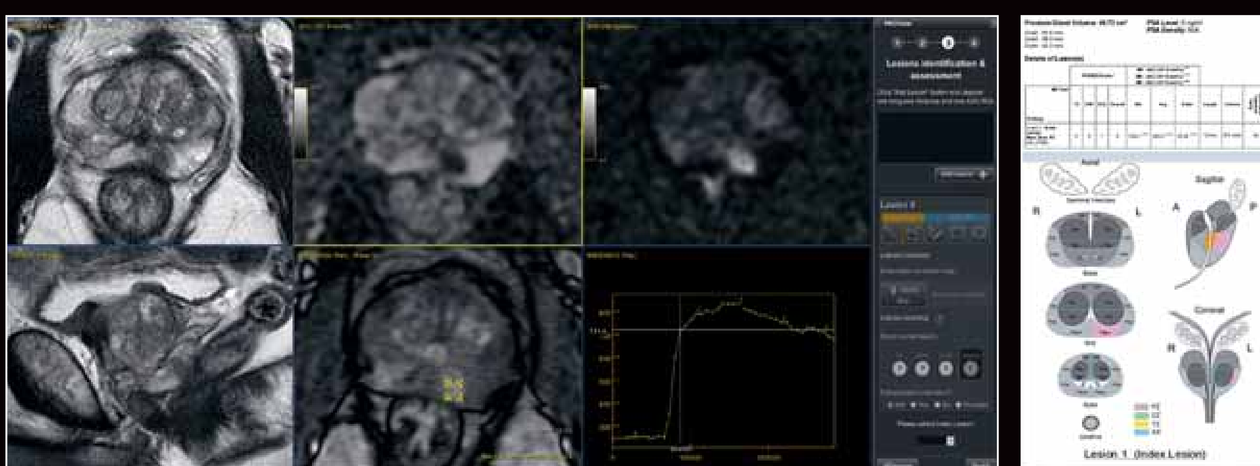


Figure 6. PROView guides workflow with prostate volume calculation, PSA density, lesion mapping and measurement.

Discussion

With the new SIGNA™Works applications—FOCUS DWI, MAGiC DWI, HyperSense and HyperCube—we are more confident in delivering accurate results for challenging multi-parametric prostate exams. The new MAGiC DWI, in combination with FOCUS DWI, are playing a key role for significant reduction of overall scan time and diagnostic confidence in the results for multi-parametric prostate MR procedures. In addition, the use of HyperSense has further reduced scan times without any discernible impact on image quality.

References

1. https://www.wcrf.org/int/cancer-facts-figures/data-specific-cancers/prostate-cancer-statistics.
2. Barrett T, Haider MA. The Emerging Role of MRI in Prostate Cancer Active Surveillance and Ongoing Challenges. AJR 2017; 208:131–139.

High-resolution synthetic diffusion MR with FOCUS in the assessment of anterior spinal cord ischemia

By Ronaldo Vosgerau, MD, staff radiologist, Institute of Neurology in Curitiba (INC), in collaboration with Eduardo Figueiredo, MR Advanced Applications Research, GE Healthcare, Brazil

SIGNA™ Architect

PARAMETERS		
	Axial Acquisition FOCUS DWI	*Sagittal Acquisition FOCUS DWI*
fFOV:	8 cm	23 cm
pFOV:	0.5 cm	0.2 cm
Slice thickness:	4 mm	2.2 mm
Spacing:	0 mm	0 mm
Freq direction:	R/L	S/I
TR:	5860 (auto) ms	2000 ms
TE:	minimum	minimum
Slices:	24	11
Frequency:	100	160
Phase:	50	32
Excitation:	FOCUS	FOCUS
B-value/NEX:	50/5, 600/10 s/mm^2	50/8, 600/16 s/mm^2
Synthetic b-value:	800/1000, s/mm^2	800/1000, s/mm^2

Introduction

MR is the gold standard imaging examination for diagnosis of suspected spinal cord ischemia and is used to exclude other causes of cord impairment.

The most conspicuous sign of ischemia is the presence of T2 spinal cord hyperintensities in different locations according to the site (artery) of involvement. A slight increase in spinal cord diameter may be present due to edema and diffusion restriction in some sites. However, diffusion MR assessment in the spinal cord is challenging mostly due to low resolution and artifacts. FOCUS DWI enables high-resolution DWI images with reduced artifacts and ADC to diminish T2 shine through. Different b-values can result in distinct conspicuity of the lesions. Multiple b-value diffusion acquisitions can add diagnostic information, however, this increases scan time, reducing patient comfort. Synthetic diffusion (MAGiC DWI) overcomes this limitation since a desired b-value image can be synthesized from a conventional dual diffusion-weighted imaging (DWI) sequence without additional scan time. In addition, the utilization of FOCUS with DWI improves overall image quality, permitting high spatial resolution diffusion images.

In this case report we describe the application of synthetic MR diffusion in combination with FOCUS in the assessment of anterior spinal cord ischemia and demonstrate its value to this challenging diagnosis.

Patient history

A 31-year-old female presented with sudden right dorsal and scapular pain along with dyspnea and upper limbs paresthesia. The patient had sought medical attention in the emergency room of her local hospital. Physical examination revealed a considerable arterial blood pressure increase at 240/120 mm Hg. After antihypertensive medication, the patient's blood pressure lowered to 170/110 mm Hg, and she was discharged with persistent upper limbs paresthesia. The following morning, the patient experienced tetraparesis and was readmitted to the hospital. She also experienced urinary retention followed by urinary incontinence and constipation. The patient was subsequently transferred to the Institute of Neurology in Curitiba (INC).

Ronaldo Vosgerau, MD
Institute of Neurology in Curitiba (INC), Curitiba, Brazil

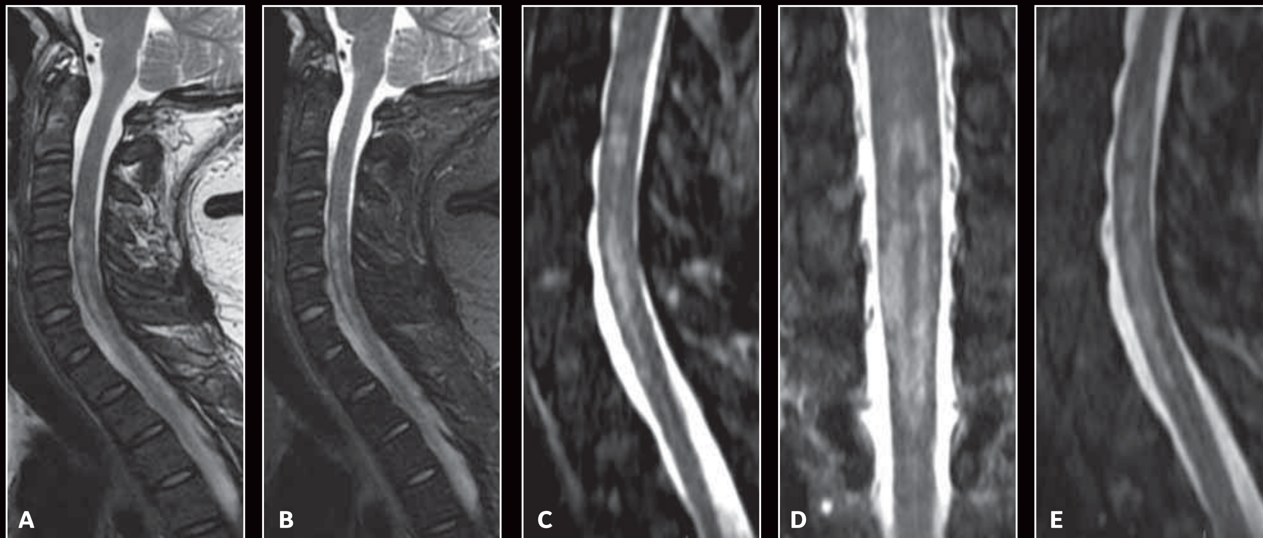


Figure 1. (A) Sagittal T2 and (B) STIR showing "pencil-like" Parasagittal spinal cord hyperintensities from C4 to T1 levels. (C,D,E) Curvilinear reformatted T2w HyperCube.

Upon admission at INC, the patient's Glasgow scale was 15, with no cranial nerve abnormalities and featured an upper and lower limb flaccid paralysis, reduced distal muscle strength (notably in lower limbs) and diminished distal reflexes. Patient also presented with painful tactile hypoesthesia and preserved vibratory sensation.

While at INC, the patient was submitted to numerous clinical investigations including: brain and spine MR; electroneuromyography; cerebrospinal fluid analysis; ECG; extensive laboratory testing (hemogram, coagulation factors, biochemical factors, hormonal infectious serology, and inflammatory and tumor biomarkers); and digital subtraction angiography.

The most remarkable findings were depicted in MR imaging and electro-neuromyography that showed absent recruitment distal to C6 in the spine.

By the end of the patient's hospital stay her muscle strength increased, albeit discretely. She was discharged and referred for motor rehabilitation.

MR protocol

MR examinations were performed in our institution's imaging department that is owned/managed by CETAC (Centro de Diagnóstico por Imagem) on a recently upgraded 3.0T MR system (formerly a Discovery™ MR750w upgraded to SIGNA™ Architect).

On the first day the cervical spine imaging protocol included Sagittal T1 (FSE), T2 (FSE and STIR); Axial T2 (FSE) and T2* (MERGE); Sagittal and Axial T1 (FSE); and FatSat (ASPIR) post-gadolinium DTPA injection. Additionally, brain, thoracic and lumbosacral spine sequences were also performed. MR diffusion imaging of the brain was acquired in the Sagittal plane to include as much of the cervical spine as possible and was performed conventionally using Spin Echo/Echo Planar (SE/EPI) diffusion-weighted imaging with a b-value of 1000 s/mm² volumetric 3D Gradient Echo FatSat of the brain, T1-weighted FatSat (FSPGR ASPIR) sequence in the Sagittal plane of the C-spine was acquired. The following day additional sequences were acquired including: Sagittal T2 (FSE); HyperCube T2-weighted, double inversion recovery (DIR) in the Sagittal plane; diffusion tensor (DTI) SE/EPI diffusion-weighted with a b-value of 800 s/mm² and 13 orientations; and a dedicated high-resolution Axial and Sagittal synthetic DWI (MAGiC DWI) with FOCUS excitation.

MR findings

The brain, lumbosacral and most of the thoracic spine (except for the cervicothoracic transition) were unremarkable. The cervical spine examination, however, was revealing. Sagittal T2 (FSE and STIR) sequences depicted a slight increase in spinal cord diameter (primarily at C5, C6 and C7 levels) along with elongated "pencil-like" Parasagittal spinal cord hyperintensities involving the C4 to T1 level. Curvilinear reformatted HyperCube was helpful to demonstrate the extension of the lesions, as well as using FOCUS with a b-value of 1400 and Synthetic DWI (Figure 6c).

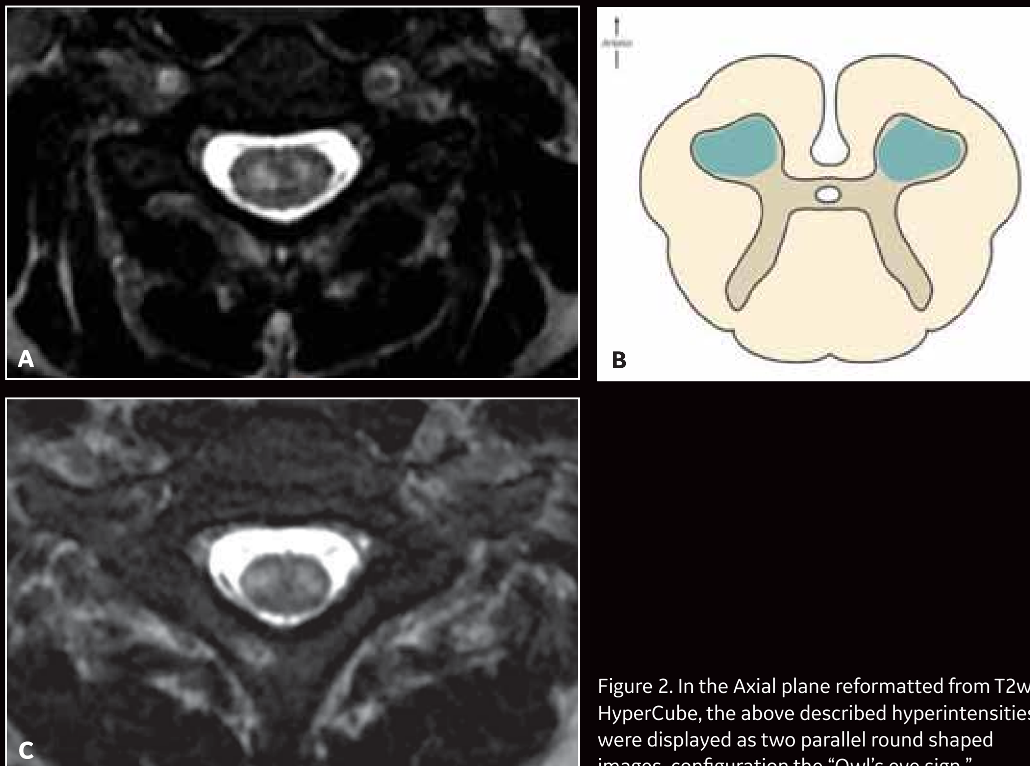


Figure 2. In the Axial plane reformatted from T2w HyperCube, the above described hyperintensities were displayed as two parallel round shaped images, configuration the "Owl's eye sign."

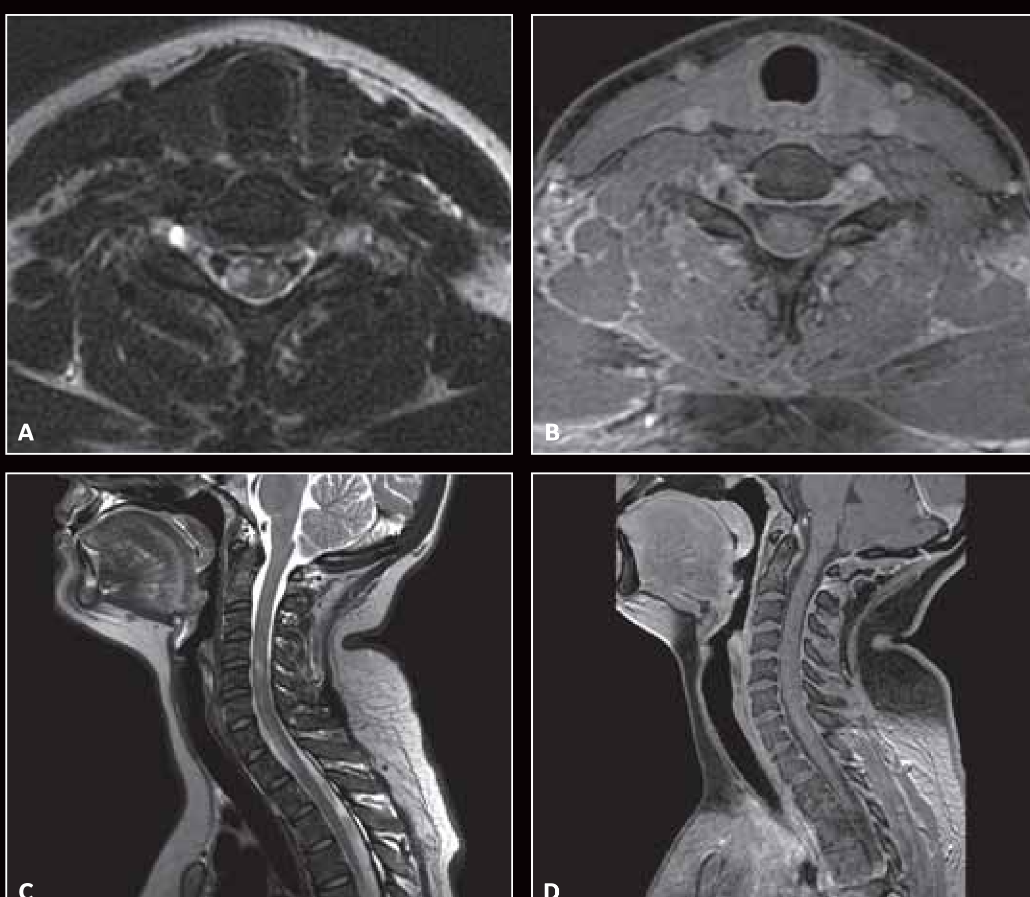


Figure 3. (A,C) Axial and Sagittal T2 and (B,D) Sagittal and Axial reformatted T1 FatSat (ASPIR) after gadolinium injection displayed apparent and slight enhancement of the intramedullary T2 hyperintensities.

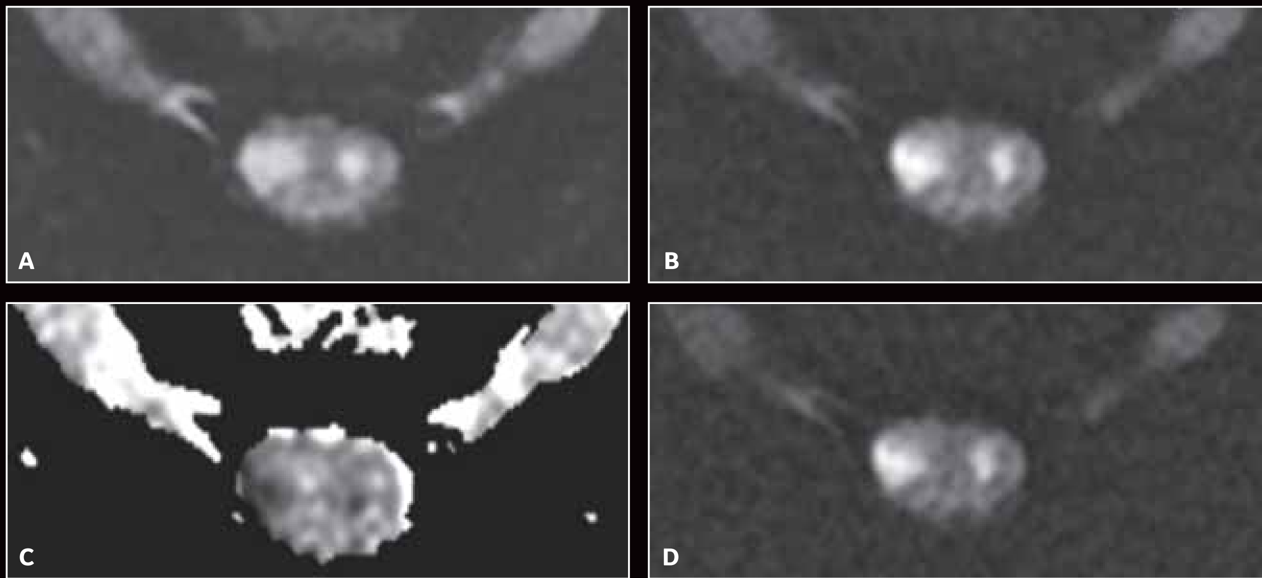


Figure 4. Axial FOCUS high-resolution 0.8 mm x 0.8 mm. (A) b50, (B) b600, (C) ADC, (D) b800 Synthetic revealed intranedullary hyperintensities. ADC showed restricted diffusion regions, removing T2 shine through artifact.

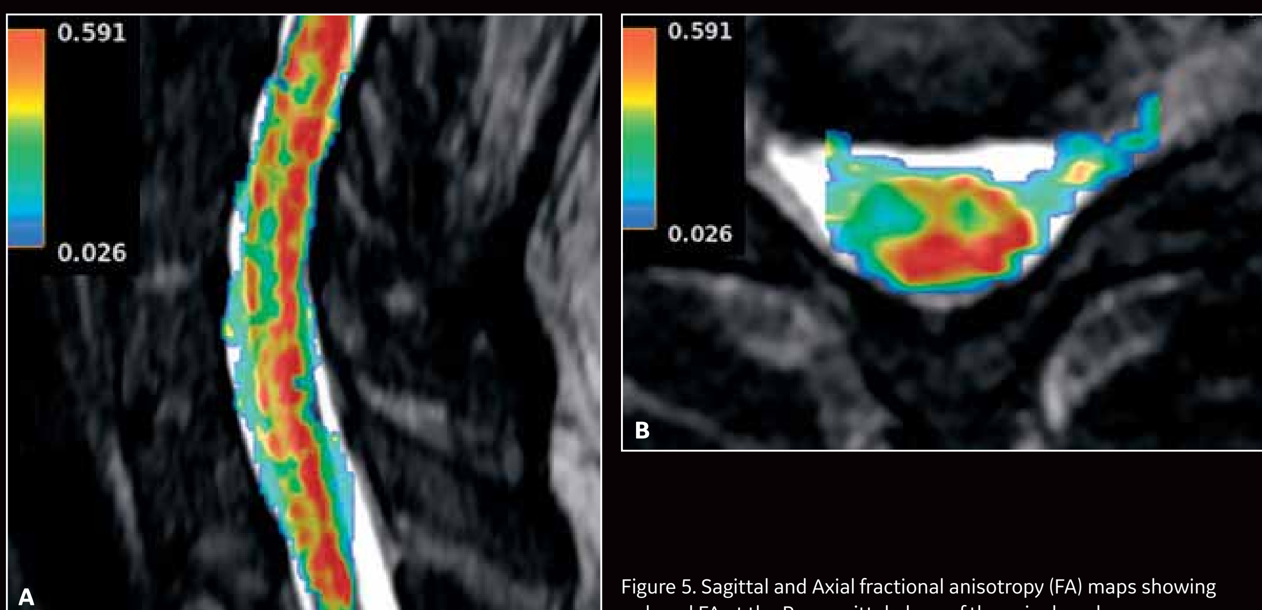


Figure 5. Sagittal and Axial fractional anisotropy (FA) maps showing reduced FA at the Parasagittal plane of the spinal cord.

In the Axial plane images that were reformatted from the T2-weighted HyperCube, the above described hyperintensities were displayed as two parallel, round-shaped images, configuration of the “Owl’s eye sign” (Figure 2).

Sagittal 3D T1 (FSE) FatSat (ASPIR) after gadolinium injection displayed apparent and slight enhancement of the intramedullary T2 hyperintensities (Figure 3).

FOCUS high-resolution 0.8 mm x 0.8 mm revealed intramedullary hyperintensities. ADC showed restricted diffusion regions, removing T2 shine through artifact (Figure 4).

Sagittal and Axial fractional anisotropy (FA) maps showed reduced FA at the Parasagittal plane of the spinal cord (Figure 5).

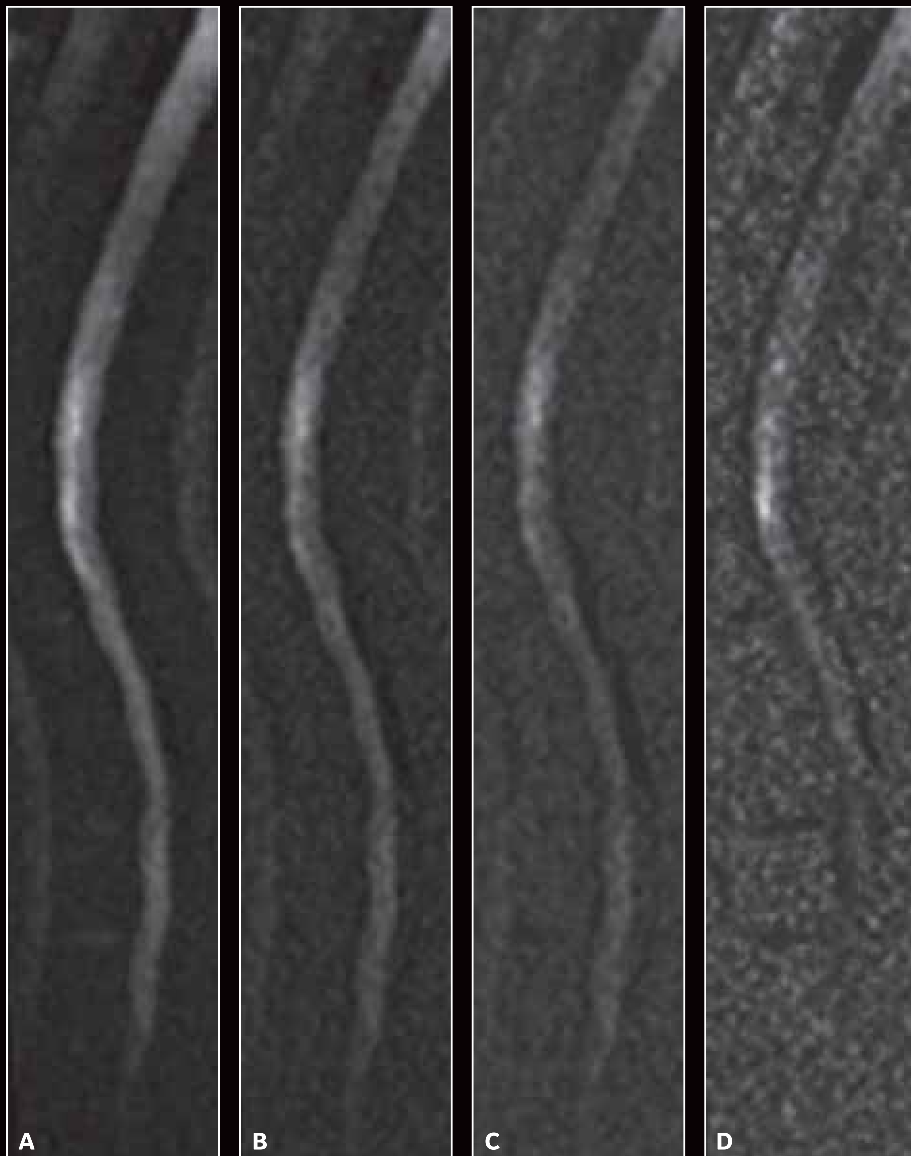


Figure 6. Synthetic DWI at b-values of (A) 800, (B) 1000, (C) 1400, (D) 2000. B-values of 800-1000 provide improved contrast and preserved spinal cord anatomy.

While FOCUS DWI was acquired with a b-value of 600, synthesized b-values of 800-1000 provide improved contrast and preserved spinal cord anatomy (Figure 6).

Based on these findings and the sudden occurrence of a neurological deficit, the possibility of an anterior spinal cord ischemia was determined to be the most likely cause of the patient's condition.

Discussion

The application of dedicated, high-resolution synthetic MR DWI with FOCUS of the spinal cord provided excellent conspicuity of the lesions depicting hyperintensities (restricted diffusion) in the Sagittal plane, appearing as "pencil-like," and on the Axial plane as "Owl's eye sign." Based on our experience, we will apply these new techniques in the future for evaluation of other spinal cord pathologies to further corroborate the clinical utility of this method. S

Citations

1. Mawad ME, et al, Spinal Cord Ischemia After Resection of Thoracoabdominal Aortic Aneurysms. Am J Neuroradiol, 1990; 11:987-991.
2. Kulkarni M, et al. Acute Spinal Cord Injury: MR Imaging at 1.5T. Radiology, 1987; 164:837-843.
3. Quencer RM, Pattany PM. Diffusion-weighted imaging of the spinal cord: Is there a future? Am J Neuroradiol, 2000; 21(7):1181-2.
4. Thurnher MM, Bammer R. Diffusion-weighted MR imaging (DWI) in spinal cord ischemia. Neuroradiology, 2006; 48(11):795-801.
5. Ghosh PS, Mitra S. Owl's eye in spinal magnetic resonance imaging. Arch. Neurol, 2012; 69(3):407-8.
6. Vargas MI, Gariani J, Sztajzel R, et al. Spinal cord ischemia: practical imaging tips, pearls, and pitfalls. Am J Neuroradiol, 2014; 36(5):825-30.

Felix Harden, BS, RT(R)(MR)(CT
Emory Johns Creek Hospital,
Johns Creek, GA

Free-breathing abdominal imaging with Auto Navigator

By Felix Harden, BS, RT(R)(MR)(CT), Supervisor of MRI, Dana McEwan, R(RT)(CT)(MR) Lead Technologist, and Anthony O. Obietan, BMSc, RT(R)(MR), Lead MRI Technologist, Emory Johns Creek Hospital, Johns Creek, GA

Abdominal MR imaging is susceptible to motion artifacts due to respiratory motion and vascular pulsation and, therefore, breath-hold techniques are often employed. However, some patients are unable to hold their breath due to age, type of disease or injury, or claustrophobia. Others are unresponsive due to advanced acuity levels, such as an ICU patient, or non-compliant as a result of neurodegenerative disease or language barrier. The addition of adding a coil for imaging can further elevate non-compliance.

Advancements in technology have helped address abdominal motion, including parallel imaging, multi-channel coils and techniques such as Auto Navigator-based imaging that tracks the motion of the diaphragm.

SIGNA™ Artist

PARAMETERS

	Axial DWI	*Axial LAVA*	*Axial T2 SSFSE*	*Axial T2 SSFSE FatSat*	*Coronal 3D MRCP*	*Coronal LAVA*	*Coronal T2*
TR:	3333 ms	6 ms	2271 ms	2133 ms	3333 ms	6.1 ms	8200 ms
TE:	61.2 ms	3.1 ms	90.7 ms	89 ms	697 ms	3.1 ms	90 ms
FOV:	36.6 x 35 cm	36.6 x 35 cm	36.6 x 35 cm	36.6 x 35 cm	37.6 x 36 cm	42.9 x 41 cm	42.9 x 41 cm
Matrix:	128 x 140	260 x 188	300 x 200	260 x 224	384 x 320	300 x 200	380 x 200
NEX:	1	0.71	0.67	0.7	1	1.4	0.6
B-value:	700						
Scan time:	3:07 min.	0:25 min.	1:57 min.	1:50 min.	2:15 min.	1:05 min.	4:25 min.
Options:	Auto Navigator/ ASSET	Auto Navigator/ ARC	Auto Navigator/ ASSET	Auto Navigator/ ASSET	RTr/Z2/FOC/ ASSET	Flx/Auto Navigator/Z2/ ARC	Auto Navigator/ ASSET

Dana McEwan, R(RT)(CT)(MR)
Emory Johns Creek Hospital,
Johns Creek, GA

Anthony O. Obietan, BMSc, RT(R)(MR)
Emory Johns Creek Hospital,
Johns Creek, GA

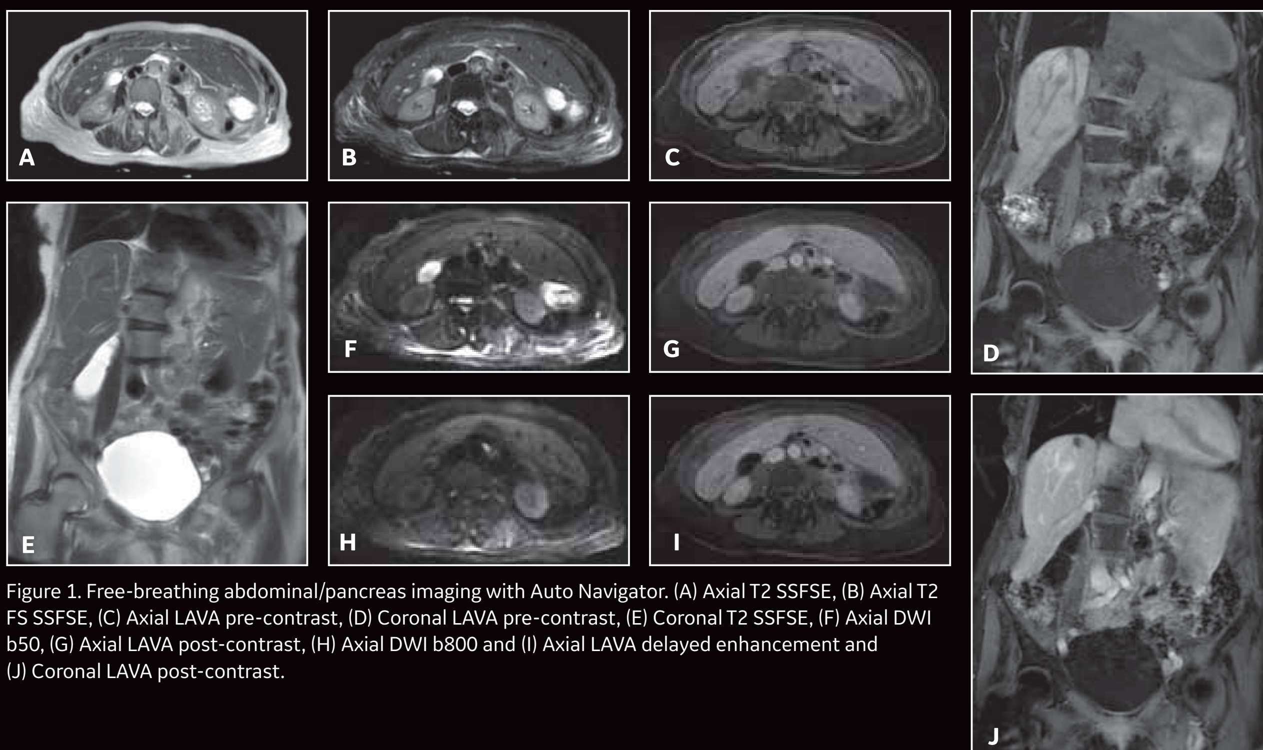


Figure 1. Free-breathing abdominal/pancreas imaging with Auto Navigator. (A) Axial T2 SSFSE, (B) Axial T2 FS SSFSE, (C) Axial LAVA pre-contrast, (D) Coronal LAVA pre-contrast, (E) Coronal T2 SSFSE, (F) Axial DWI b50, (G) Axial LAVA post-contrast, (H) Axial DWI b800 and (I) Axial LAVA delayed enhancement and (J) Coronal LAVA post-contrast.

Auto Navigator is a free-breathing approach used to combat respiratory motion for body, cardiac and chest imaging with automatic tracker placement. It is compatible with all critical body imaging sequences, such as DWI, PROPELLER, SSFSE, MRCP and dynamic T1 imaging such as LAVA, LAVA Flex, DISCO. The navigator tracker is automatically placed over the right hemidiaphragm and synchronizes with the patient's breathing pattern. Acquisition is synchronized to the patient's diaphragmatic movement and thus minimizes respiratory ghosting artifacts. Real-time adjustment allows threshold levels to be adjusted during the acquisition, eliminating failures due to changes in respiratory patterns of the patient.

The Auto Navigator option is easy to use and learn. The technologist turns it on in Imaging Options, and depending on the application, it will gate or trigger the patient's respiratory cycle. It is really that simple to use. The tracker is automatically placed at the dome of the liver. This is expecially useful if the patient has low respiration since we can immediately switch to Auto Navigator to preserve image quality. Traditional methods like respiratory trigger/gating cannot do this.

There is no time penalty with using Auto Navigator, and in many instances it shortens the time the patient is in the scanner when compared to having to repeat a sequence due to motion artifacts. We have found

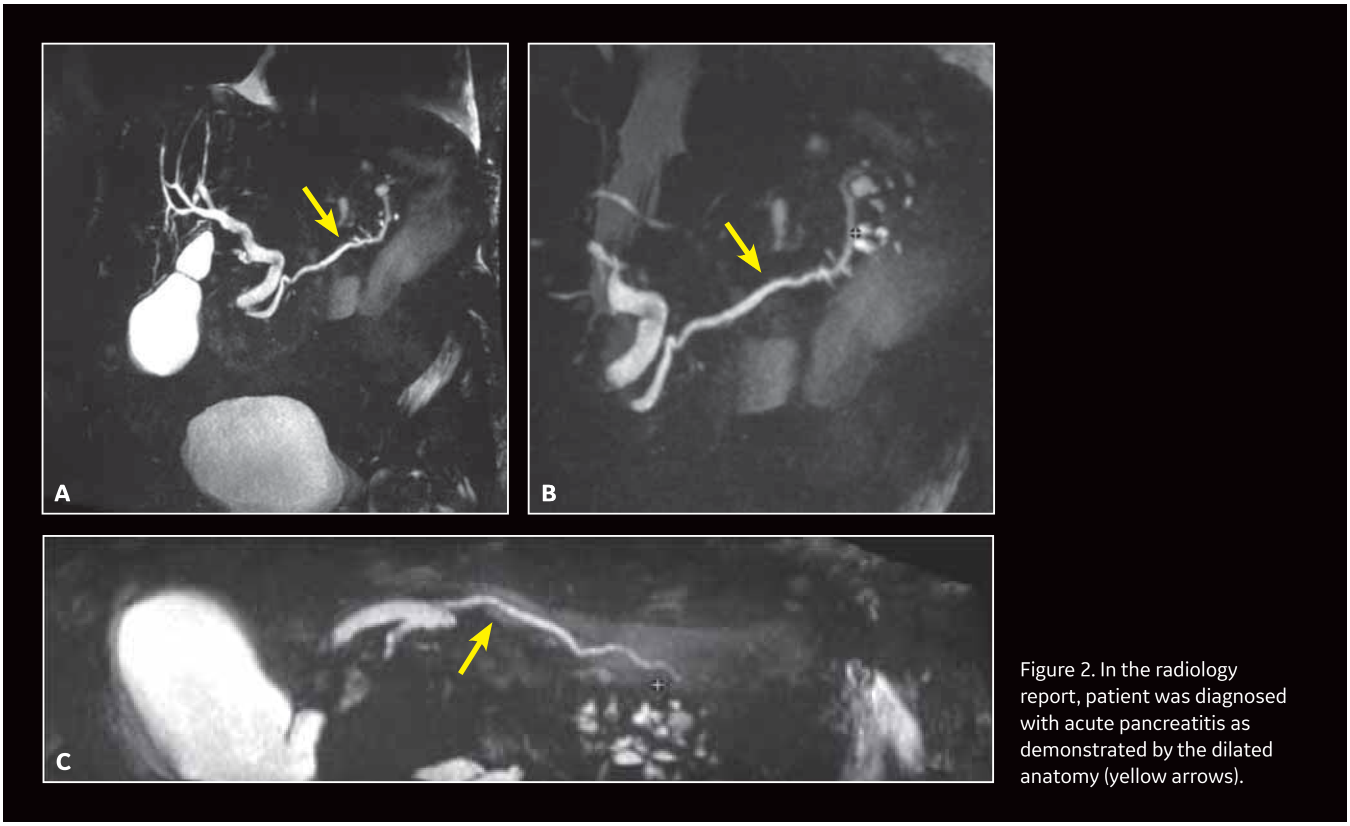


Figure 2. In the radiology report, patient was diagnosed with acute pancreatitis as demonstrated by the dilated anatomy (yellow arrows).

Auto Navigator delivers the image quality our radiologists want for their diagnosis and is reliable and repeatable. Therefore, we have a high confidence in using it when needed.

At our facility, we have found the Auto Navigator-based imaging feature on the SIGNA™ Artist to be a valuable tool when imaging patients who cannot follow instructions or are unresponsive. On average, we'll have at least 10 cases each month where the Auto Navigator option is employed.

Patient history

A 91-year-old female with a history of generalized abdominal pain was referred for MR. She was hard of hearing, unable to hold her breath and had bilateral pleural effusions.

MR findings

According to the radiology report, the patient suffers from acute pancreatitis as demonstrated by the dilated anatomy (Figure 2, arrows). Acute pancreatitis is an inflammation of the pancreas that develops quickly with the main symptom being abdominal pain. It usually settles in a few days but sometimes it becomes severe and very serious.

Discussion

The ability to acquire high-quality images on all patients regardless of their ability to hold their breath or understand the breathing instructions is paramount to diagnostic confidence and patient management. S

Diffusion imaging demystified

By Heide Harris, RT(R)(MR), Global MR Clinical Marketing Training Manager, and Steve Lawson, RT(R)(MR), Global MR Clinical Marketing Manager, GE Healthcare

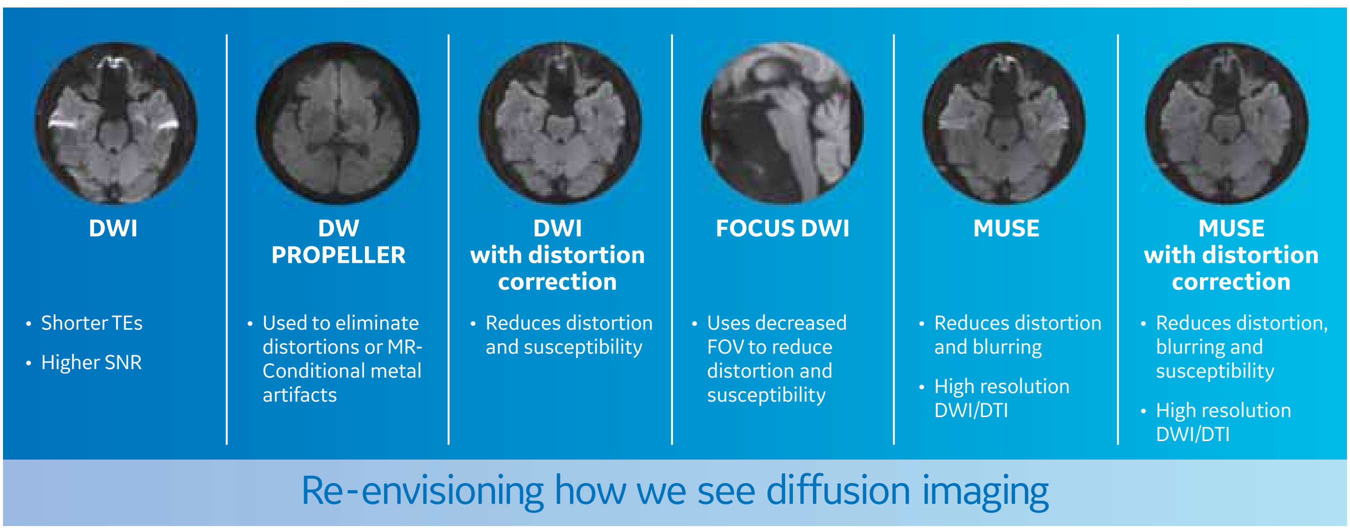


Figure 1. The GE Healthcare MR diffusion evolution.

The availability of echo-planar imaging (EPI) in the early 1990s helped make diffusion-weighted imaging (DWI) a clinical possibility. Prior to this, early DWI MR sequences were slow and, therefore, sensitive to respiratory motion artifacts. EPI solved this issue, and some of the early clinical work demonstrated the value of DWI in the early detection of acute stroke.[1]

DWI exploits the concept that molecular motion in tissues isn't free. This can be particularly useful to produce high contrast images in cases of increased hypercellularity due to the presence of lesions, inflammatory disease, traumatic injury and ischemic-related cytoxic edema. Other techniques like diffusion tensor imaging (DTI) can exploit how water molecular movement is directionally aligned with the structure of the tissue being imaged. Additionally these techniques can provide quantitative information for further interrogation of the tissues beyond qualitative assessments. The purpose of this article is to review the concepts of DWI as well as options and tools currently available on SIGNA™ Works.

How it works

DWI relies on the incoherent thermal motion of water molecules (Brownian motion) within a voxel of tissues. Diffusion is the movement of molecules in a structure between two time points (t_0 to t_1), thus providing a window to tissue microstructure. In tissue, diffusion of water follows a specific pattern based on the structure and properties. There exists a concentration difference between two compartments and a macroscopic flow can be observed between them. This flow can be described by Fick's law:

$$J = - D \nabla C$$

Whereas, D is the diffusion coefficient and can be determined by the ratio of the flux and the concentration gradient. The diffusion gradients can be applied in individual directions or combined and applied in all directions. The simplest application is to use a simple, bipolar-pulsed gradient experiment. The static spins will produce no dephasing, and the moving spins will produce a dephasing that is dependent upon the spin history during the time interval D between the pulses.

Diffusion can be qualitatively visualized on MR images and diffusion restriction quantitatively measured using the parameter apparent diffusion coefficient (ADC) values. By studying the changes in diffusion, radiologists can visualize internal physiology to detect abnormalities and evaluate tumor characteristics or ischemia.

Characteristics/terminology

b-value

B is a value that includes all gradient effects (imaging gradients + diffusion gradients) and can be regarded as analogous as the TE for the T2-weighting. The signal attenuation depends on both the ADC and the gradient strength (b-value). Generally, an increase of the b-value increases the diffusion weighting (the signal attenuation) but it also decreases the SNR of the image.

ADC

ADC is a variable parameter expressed in mm^2/sec that reflects the physical properties of the tissues. It is not dependent on the magnet field strength or pulse sequence used (e.g., T1 or T2) and can be compared when obtained at different times in a given patient. In true diffusion images (ADC map), the contrast is opposite to diffusion-weighted images: high signal corresponds to high, fast diffusion, and darkness corresponds to low, slow diffusion.

Concepts

When DWI is added to conventional MR sequences such as T2 or T2-weighted, the radiologist has both anatomical images and diffusion-related changes in the tissue for a confident diagnosis.

DWI images and ADC maps depict hyperintense and hypointense signal in tumor regions. However, these images are often lower resolution and can suffer from artifacts caused by distortion and noise. These challenges can be addressed through the use of multi-shot and non-EPI sequences; optimizing echo time (TE), repetition time (TR) and the number of b-values; post-processing; higher field strength scanners; more powerful, faster gradients; and improvements to MR hardware.

Higher field strength scanners deliver better contrast, resolution and SNR. Highly stable and powerful gradients that provide a more homogenous field for B_0 and RF pulse ensure accuracy in imaging. Fast-switching gradients can minimize eddy currents and related artifacts, minimize susceptibility artifacts, reduce acquisition time and provide good SNR. TE is a good indicator of the gradient performance when it comes to diffusion imaging.

There are a number of different options for DWI, a critical clinical imaging sequence that continues to evolve. Single-shot EPI is the conventional method that provides the ability to focus in on a specific area using a small FOV. Multi-shot DWI delivers higher resolution with a reduction in distortions. Diffusion scans can also be acquired with free breathing by utilizing Auto Navigator-based acquisitions to minimize motion artifacts. Other features like MAGiC DWI and PROGRES further improve diffusion quality by optimizing acquisition parameters such as TE, TR and the number of b-values to provide more diffusion-weighted measurements, resulting in a more accurate ADC value.

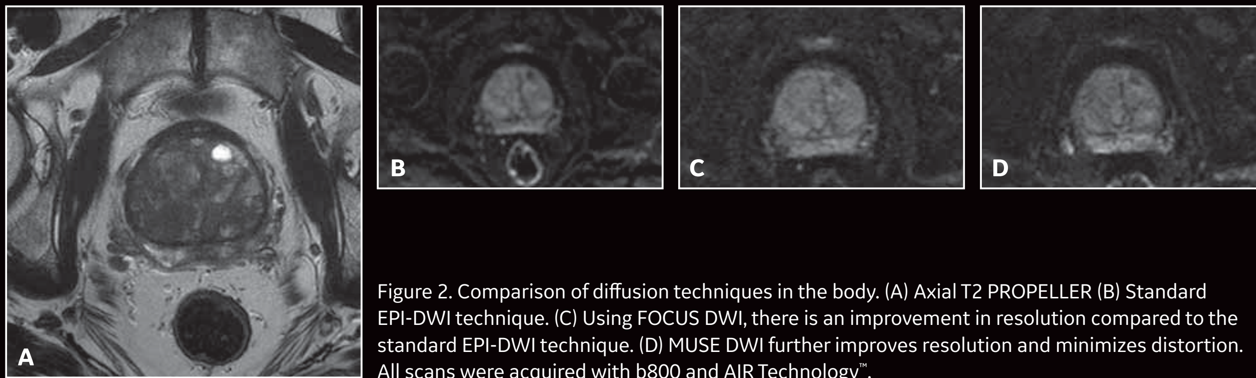


Figure 2. Comparison of diffusion techniques in the body. (A) Axial T2 PROPELLER (B) Standard EPI-DWI technique. (C) Using FOCUS DWI, there is an improvement in resolution compared to the standard EPI-DWI technique. (D) MUSE DWI further improves resolution and minimizes distortion. All scans were acquired with b800 and AIR Technology™.

SmartNEX allows GE users to customize the NEX value being used at each b-value by only increasing the signal averages with higher b-values to enable shorter scan times.

GE DWI sequences

DWI

DWI is most widely used clinically as an aid to evaluate acute and hyperacute stroke, tumoral (cerebral lymphoma), infectious (herpes encephalitis), degenerative, inflammatory and traumatic pathology. The echo planar sequence is generally preferred in the head or body for its speed, which limits motion artifacts (macroscopic). In the body, DWI enables early detection and characterization of focal lesions in the prostate and liver, including metastases, focal nodular hyperplasia, hepatocellular carcinoma and benign hepatocellular lesions. It can also help clinicians evaluate patient prognosis and treatment efficiency and optimization.

FOCUS DWI

FOCUS (FOV Optimized and Constrained Undistorted Single-Shot) DWI uses a multi-dimensional selective excitation to zoom in on the field of view (FOV), which controls excitation in slice and phase-encoding directions. It is compatible with multi-b, multi-NEX (SmartNex), FatSat methods and DTI options. FOCUS DWI delivers high spatial resolution to improve conspicuity and morphology with fewer artifacts due to distortion, susceptibility and blurring. In the body, FOCUS DWI provides robust image quality even in challenging body areas such as the rectum, pancreas, breast and spinal cord.

MUSE

MUSE (MUltiplexed Sensitivity Encoding) reduces blurring and susceptibility induced distortions that result from the longer readout length and echo spacing of traditional DWI. Compared to conventional parallel imaging techniques, MUSE pushes the boundaries of spatial resolution for DWI. It is particularly beneficial in anatomical areas that are vulnerable to susceptibility artifacts, such as the brain and prostate. MUSE allows for segmented acquisition in the phase encoding direction by mitigating shot-to-shot, motion-induced phase errors that are inherent to multi-shot diffusion. Distortions are reduced, allowing for higher resolution and the acquisition of diffusion data with segmented readout along phase encoding directions.

The number of shots available with MUSE is based on coil and acceleration factors. In brain imaging, a typical scan is a combination of 2 shots and ASSET x2, allowing for a reasonable scan time with reduced artifacts while maintaining good SNR. It can also be used with distortion correction for further reduction of signal pile-up. In prostate imaging, a typical scan is a combination of two or three shots and ASSET x1. While it's possible to scan more shots with ASSET x1, it leads to a longer scan time. Also, using more shots with higher acceleration (e.g., 3 shots / ASSET x2, or 4 shots / ASSET x2) can lead to phase estimation errors and poor image quality. It's critical the FOV includes all of the anatomy in the phase direction and the scan emcompasses air-to-air coverage to prevent wrapping.

MUSE allows for high-resolution imaging that pushes the boundaries of spatial resolution and SNR in DWI.

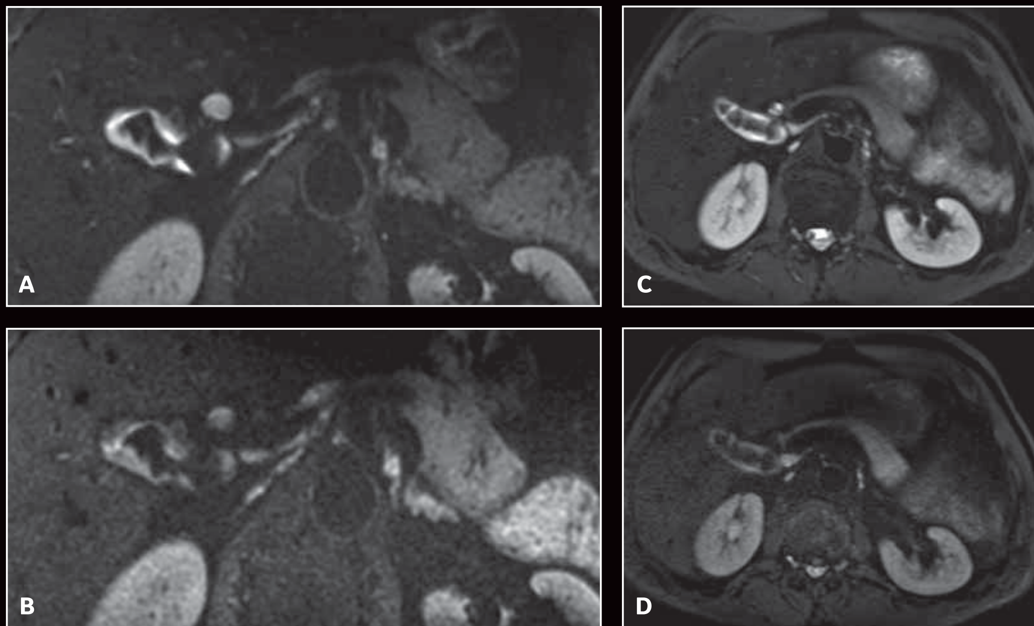


Figure 3. Axial FOCUS DWI at (A) b50 and (B) b500. Axial MUSE DWI (C) b50 and (D) b800.

DW PROPELLER

DW PROPELLER was designed to be more robust to greatly reduce distortions from MR-Conditional implants or metal, such as aneurysm clips or braces, as well as for challenging areas like the middle ear cholesteatoma. DW PROPELLER is a radial Fast Spin Echo (FSE)-based sequence as opposed to DW EPI, which is susceptible to severe distortion caused by main B_0 magnetic field inhomogeneities. The latest release of DW PROPELLER provides shorter scan times by eliminating the additional 90-degree RF pulse that diffusion prep uses, preserving almost two times as much signal and saving scan time. Newly available spatial SAT and shim volumes help improve image quality and reduce artifacts. DW PROPELLER is now compatible with all planes, oblique scans and Flexible No Phase Wrap. DW PROPELLER is also compatible with ART (Acoustic noise Reduction Technique) to create a Silent diffusion scan.

DTI/FiberTrak

Diffusion Tensor Imaging (DTI)/FiberTrak helps clinicians visualize white matter trajectories in the brain by generating color-coded directional maps or 3D white matter trajectories. It is a technique that produces image contrast proportional to the local diffusion coefficient of water (up to 300 different diffusion directions). DTI consists of a 90-degree excitation pulse and a 180-degree RF Pulse with a pair of DW gradients in the three axes. Both the diffusion coefficient and its directional dependence can be measured using DTI. This sequence creates a set of diffusion-weighted images and T2-weighted images that are used to fully characterize the diffusion tensor at each voxel. The single-shot FOCUS DWI and MUSE can all be DTI techniques.

DTI acquires diffusion data along six to 300 diffusion orientations at each prescribed slice location and generates image contrast based on the degree of diffusion anisotropy in cerebral tissues, such as white matter. With DTI, radiologists can visualize white matter in the brain as ADC, fractional anisotropy maps and T2-weighted TRACE maps. In the brain's white matter, the diffusion value depends on the orientation of the myelin fiber tracts and on the gradient direction: anisotropic, or bright, is the preferred elliptic direction; isotropic, or dark, is not elliptic with no preferred direction.

FiberTrak post-processing generates eigenvector information from the diffusion tensor acquisition and processing. Three-dimensional renderings of the diffusion along white matter tracts are generated, and the color orientation illustrates the orientation of the white matter tracks (and the anisotropic fraction).

Clinical use of DTI/FiberTrak includes: acute ischemic stroke; epilepsy; various brain trauma; detection of lesions; white matter; Alzheimer's disease; psychiatric pathology, (e.g., schizophrenia); neonatal brain maturation and development (myelinization); and tumoral pathology.

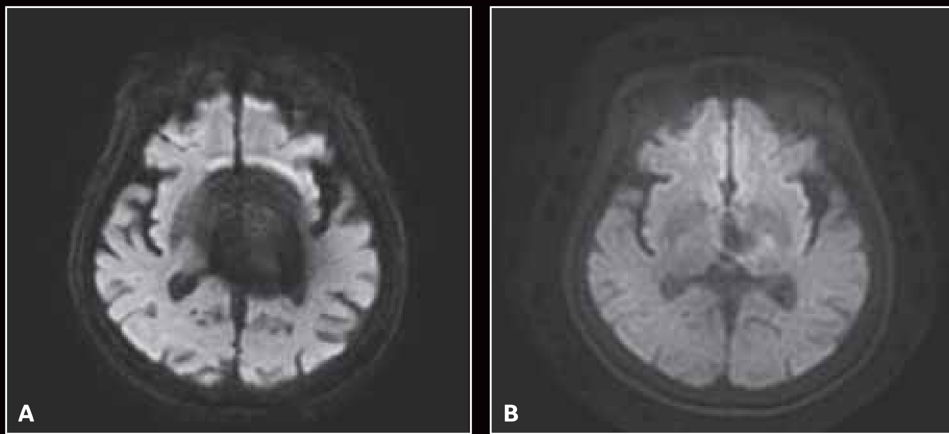


Figure 4. DW PROPELLER is a radial Fast Spin Echo-based sequence that helps improve image quality and reduce artifacts. These images are from a patient with an MR-Conditional aneurysm clip. DW PROPELLER can also be used as a Silent diffusion.

Images courtesy of University of Yamanashi Hospital.

Multi-shell DTI is another advanced diffusion sequence and currently used in the Human Connectome Project. However, it is research-based.

PROGRES

PROGRES, a distortion correction technique, is one of the newest applications introduced by GE. Although developed in unison with the SIGNA™ Premier, it will become available on other systems within the GE MR Portfolio.

Distortion correction uses a combination of three components to address sources of distortion. An integrated, reverse polarity T2 acquisition corrects for B_0-induced distortions in the phase encoding direction by scanning two passes: forward PE and reverse PE. Also included are corrections for both rigid motion and eddy current.

Distortion correction is most effective with high SNR scans, as reduced SNR can lead to a blurred appearance. The best results are when it is combined with MUSE in brain applications.

MAGiC DWI

MAGiC DWI is a synthetic DWI sequence that calculates multiple b-values rather than acquiring them. As noted previously, the higher the b-value the lower the SNR. Therefore, by acquiring the diffusion with a b-value of 800 and then synthetically creating a higher b-value, (e.g., 2000), it is possible to maintain the SNR from the lower b-value acquisition. From a single DWI scan, multiple b-values can be generated, including high b-values, such as those required by PI-RADS™ for prostate. In fact, MAGiC DWI provides higher b-values than what can be achieved by acquiring them, and also allows shorter TE, which improves SNR and image sharpness. Unique to this sequence is that b-values can be generated even after the scan is completed and the patient gone. MAGiC DWI is compatible with all diffusion scans as long as there are two values acquired (b0 + b1000 or b50 + b800).

HyperBand

HyperBand takes diffusion to a new level of productivity by allowing the acquisition of more slices or diffusion directions within a typical scan. It excites and acquires multiple slices simultaneously to shorten acquisition time and can be combined with ARC for high acceleration factors.

Diffusion imaging has certainly come a long way from when it was first introduced. It has become a gold standard for MR imaging throughout the body. While there are many different options, think of it as multiple tools in your toolbox to tackle the job that is needed. Table 1 provides a quick guide for GE MR users. We hope you find this information useful and applicable in your practice. S

References

1. Baliyan V, Das CJ, Sharma R, Gupta AK. Diffusion weighted imaging: Technique and applications. World J Radiol. 2016 Sep 28; 8(9):785-798.
2. Chilla GS, Tan CH, Zu C, Poh CL. Diffusion weighted magnetic resonance imaging and its recent trend—a survey. Quant Imaging Med Surg. 2015 Jun; 5(3):407-22.

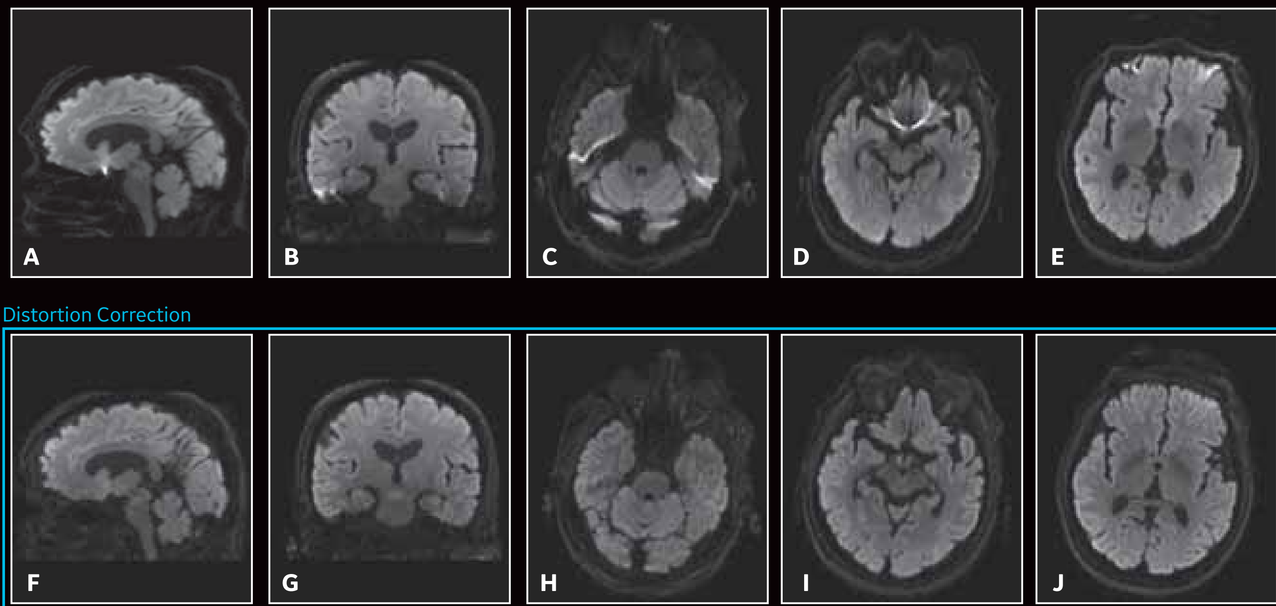


Figure 5. Axial DTI, 2 mm^3, b1000 with HyperBand. (A-E) Images demonstrate the inherent susceptibility artifacts normally associated with diffusion imaging. (F-J) Images demonstrate the impact of distortion correction (PROGRES) to improve the susceptibility.

DWI sequence	What is it?	Where best used	Compatible with	Diffusion direction options
DWI	A single-shot EPI pulse sequence designed to create images based upon measuring the random Brownian motion of water molecules within a voxel of tissue.	A traditional diffusion technique used anywhere in the body for tumor characterization or ischemic changes.	HyperBand, Auto Navigator, FatSat, SPECIAL, ASPIR, SmartNEX	All, 3 in 1, Tetra, single slice direction, tensor
FOCUS DWI	2D Spatially Selective RF Excitation method for DW-EPI and DTI designed to reduce FOV in-phase encode direction within the imaging plane, decreasing geometric distortion and eliminating phase wrap artifacts.	Brain (orbits, base of skull, or any small FOV), spine, pancreas, prostate, uterus, breast and kidneys.	HyperBand, Auto Navigator, FatSat, SPECIAL, ASPIR, SmartNEX	All, 3 in 1, Tetra, single slice direction, tensor
DW PROPELLER	FSE-based sequence with diffusion lobes used to minimize or eliminate distortions and SNR loss found with standard DWI acquisitions.	High susceptibility areas such as base of skull, dental work, tissue boundaries; MR-Conditional implant imaging like MR safe aneurysm clips. *Note: in later software releases, it can be used throughout the body.*	ART (for a Silent MR exam), FatSat	All, single slice direction only
MUSE	A multi-shot diffusion that acquires a segmented scan in the phase encoding direction, which mitigates shot-to-shot, motion-induced phase errors inherent in multi-shot diffusion and DTI scans.	Brain, liver, prostate. The result is images with reduced blurring and susceptibility artifacts.	Auto Navigator, FatSat, SPECIAL, ASPIR, SmartNEX, DTI	All, 3 in 1, Tetra, single slice direction, tensor
DTI	A technique that produces image contrast proportional to the local diffusion coefficient of water. Both the diffusion coefficient and its directional dependence can be measured using DTI.	DTI is used for brain and neuro applications. It is most commonly used for white matter tract visualizations. It can also be used in the spine and brachial plexus.	HyperBand, FatSat, SPECIAL, ASPIR, SmartNEX	tensor
MAGiC DWI	Synthetic DWI calculates multiple b-values synthetically rather than acquiring them.	Can be used anywhere in the body that requires a higher b-value diffusion; Can be done as an integrated scan or post processed.	Must have 2 b-values acquired (for example: B0 + B1000 or B50 + B800).	All, 3 in 1, Tetra, single slice direction
Distortion correction (PROGRES)	An imaging option that reduces the distortion that normally occurs with diffusion imaging by using a combination of integrated correction techniques.	Brain and prostate imaging.	HyperBand, DWI, DTI, MUSE. Best IQ on scans with optimal SNR.	All, 3 in 1, Tetra, single slice direction, tensor

Table 1.

Artificial intelligence:

shaping the future of healthcare

Based on a presentation by Chris Austin, MD, MSc, formerly Medical Director, Imaging AI and Analytics at GE Healthcare

Artificial intelligence (AI) is everywhere. It's in our phones, cars, kitchens, homes and even in our suitcases. In healthcare, the emergence of AI has some providers excited, some skeptical and some concerned for their future. Yet, the world of humanoid robots completely removing doctors from frontline patient care is unlikely. Machines will also not replace radiologists. Rather, by combining the human and the machine together, there is great potential to dramatically improve the productivity, clinical quality and cost of healthcare globally.

Research points to an upward trajectory for the role of and potential impact of AI. Global GDP is estimated to be up to 14% higher in 2030 as a result of the accelerating development and adoption of AI.[1] AI could contribute up to $15.7 trillion[1] to the global economy in 2030, more than the current output of China and India combined. Of this, $6.6 trillion will likely come from increased productivity and $9.1 trillion will come from the side effects of increased consumption in the new AI-enabled economy.[1]

Labor productivity improvements are expected to account for over 55% of all GDP gains from AI between 2017 – 2030. The impact on productivity could be competitively transformative—businesses that fail to adapt and adopt could quickly find themselves undercut on turnaround times as well as costs. They stand to lose a significant amount of their market share as a result. Importantly, the potential of this initial phase of AI adoption mainly centers on enhancing what's already being done, rather than creating more that's new.

What does AI mean for the clinical practice and business of radiology? Modern radiology continues to face productivity challenges with the demand for advanced imaging going up and the supply of radiologists in many developed markets plateauing or in decline. Over the last decade, demand for MR imaging in the UK has increased on average by 13.2 percent each year[2] and nearly nine percent of consultant radiology posts were unfilled in 2016.[3] In the US, approximately 49 percent of radiologists report burnout symptoms and one report estimates more than 1,100 additional radiologists are needed in the country by 2020 to match supply with demand.[4] The workload for radiologists in Japan is 4.3 times the global average; 2.5 times the number of current radiologists will be needed in Japan to provide sustainable and quality healthcare.[5]

Improving clinical quality remains the ongoing focus of all practicing clinicians and healthcare provider organizations. Radiology is no exception when it comes to improving clinical quality. An estimated 40 million radiologic errors occur per annum,[6] with the average error rate hovering around 30 percent based on retrospective studies.[7] It's not just about avoiding errors in reading the image. Opportunities to improve clinical quality arise along the entire radiology workflow, from avoiding data entry errors at the time of ordering an imaging exam, to incorrect patient information, to using the wrong protocol or selecting a less appropriate modality to best answer the clinical question being asked.

The World Health Organization has said that the global radiology gap, "is far less discussed than infectious disease outbreaks and natural disasters, but its dangers to public health are every bit as urgent."

Nearly 70% of residents in developing countries do not have access to basic diagnostic radiology services.[8] For example, in Kenya with a population of 43 million, there are 200 radiologists in the entire country.[8] At Massachusetts General Hospital, there are 126 radiologists linked to the hospital. [8]

We need better outcomes in healthcare in terms of reduced costs, improved quality and efficient services... and AI can help. Industry and clinical partnerships comprised of healthcare facilities, IT, data sources and professional organizations are critical to the success of a healthcare AI environment.

GE Healthcare has embraced the future of healthcare with AI by connecting physicians and patients with organized data. Disjointed, heterogeneous data is increasing beyond the processing ability of the human brain. AI can organize and analyze patient information to efficiently perform complex tasks that can help clinicians deliver better diagnosis and treatment plans.

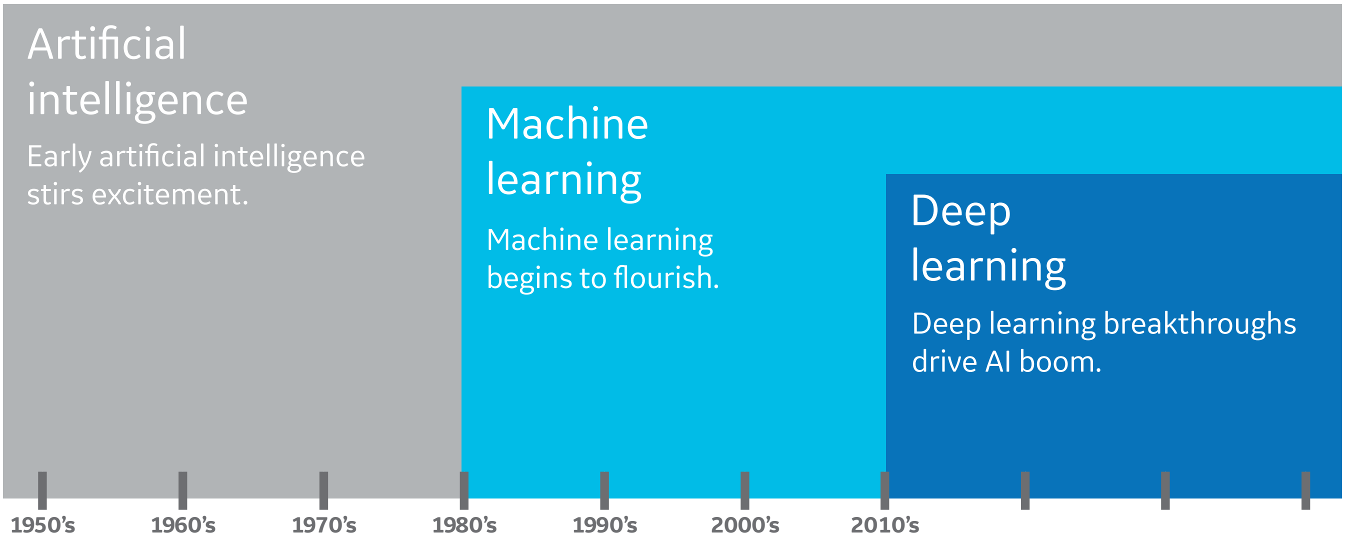


Figure 1. A timeline of AI, machine learning and deep learning. AI is teaching a computer to act like a human. It has knowledge about the world and can learn, reason, plan, communicate and manipulate objects. Machine learning is a subfield of AI. It is a data-driven approach that can learn from data without being explicitly programmed. Deep learning is a subfield of machine learning where a "neural network" that is biologically inspired can automatically learn hierarchical representations.

By looking at opportunities across the entire value chain we can build systems that will improve over time. GE Healthcare has partnered with UCSF, Boston Children's Hospital, UPMC and Partners Healthcare to develop an AI library. This compilation includes deep learning algorithms, design and commercialized technologies to advance diagnosis and treatment, AI-enabled workflow and clinical productivity solutions to improve patient outcomes across multiple care areas and medical specialties.

At GE, making devices more intelligent is a first step in addressing productivity and clinical challenges. In MR, GE's vision for AI includes simplifying and organizing MR images for fast evaluation of patients and providing quantifiable morphometry for clinical decision making. GE will also be exploring the use of AI to revolutionize the way MR scans are planned and executed by incorporating contextual data about the patient history and prior scans into the parameter selection. It may also be possible that AI can help detect artifacts intra-scan and alert the technologist if they need to re-scan. Finally, the anticipated deployment of deep learning may assist in reconstructing better images from sparse data in less time and developing tools that help in identifying, segmenting and classifying abnormalities.

Today, GE has nearly 400 patents for machine learning and 50 patents for deep learning. Nearly $2 billion has been invested in more than 100 industry-leading advanced visualization applications. In addition to 20-plus academic partnerships, GE is also collaborating with leading technology companies, such as NVIDIA, Intel and Microsoft™.

Radiology will be augmented by AI, it is only a matter of time. In the words of one anonymous radiologist blogger, "The only radiologists whose jobs may be threatened are the ones who refuse to work with AI." Ⓢ

References

1. https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf.
2. https://www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2014/11/Annual-Statistical-Release-2014-15-DID-PDF-1.1MB.pdf.
3. https://www.rcr.ac.uk/publication/clinical-radiology-uk-work-force-census-2016-report.
4. https://www.jacr.org/article/S1546-1440(15)01218-1/fulltext.
5. Nakajima et al, Radiat Med (2008) 26:455–465. Radiat Med. 2008 Oct;26(8):455-65.
6. Bruno MA, Walker EA, Abujudeh HH. Understanding and confronting our mistakes: the epidemiology of error in radiology and strategies for error reduction. Radiographics. 2015;35:1668–1676.
7. Error and discrepancy in radiology: inevitable or avoidable? Insights Imaging Feb 2017.
8. Silverstein J. Most of the World Doesn't Have Access to X-rays. The Atlantic, Sept 27, 2016. Available at: https://www.theatlantic.com/health/archive/2016/09/radiology-gap/501803/.

Peder Larson, PhD
University of California, San Francisco,
San Francisco, California,

The sound of silence

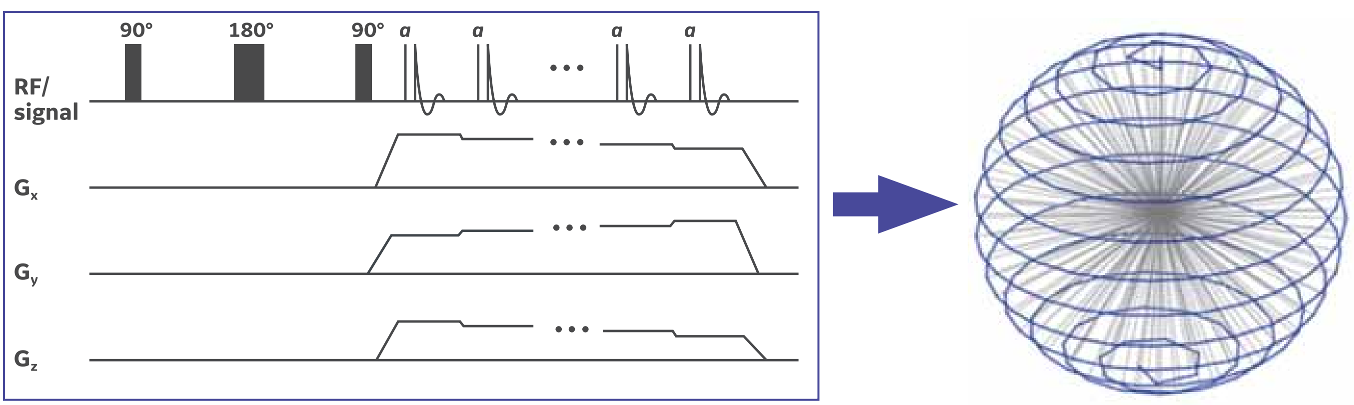


Figure 1. Silent fMRI pulse sequence diagram and *k*-space trajectory

Functional MRI (fMRI) measures the small changes in blood flow that result from brain activity. The technique can uncover abnormalities in the brain and assess the effects of stroke, trauma or degenerative diseases such as Alzheimer's. It is also used for surgical or radiation therapy planning in the brain to assess potential risks resulting from these invasive treatments. However, standard fMRI sequences are extremely loud and may impact brain function.

"That noise is being perceived by the person in the scanner and we have to expect this results in a biological effect on brain function," says Peder Larson, PhD, Associate Professor and a Principal Investigator in the Department of Radiology and Biomedical Imaging at the University of California, San Francisco. "There are also subsets of the population where we want to examine how disease compromises brain function, such as people with autism, schizophrenia or depression. fMRI is an important tool for these studies, yet, with the loud noise disrupting their thinking, we often cannot study these types of patients."

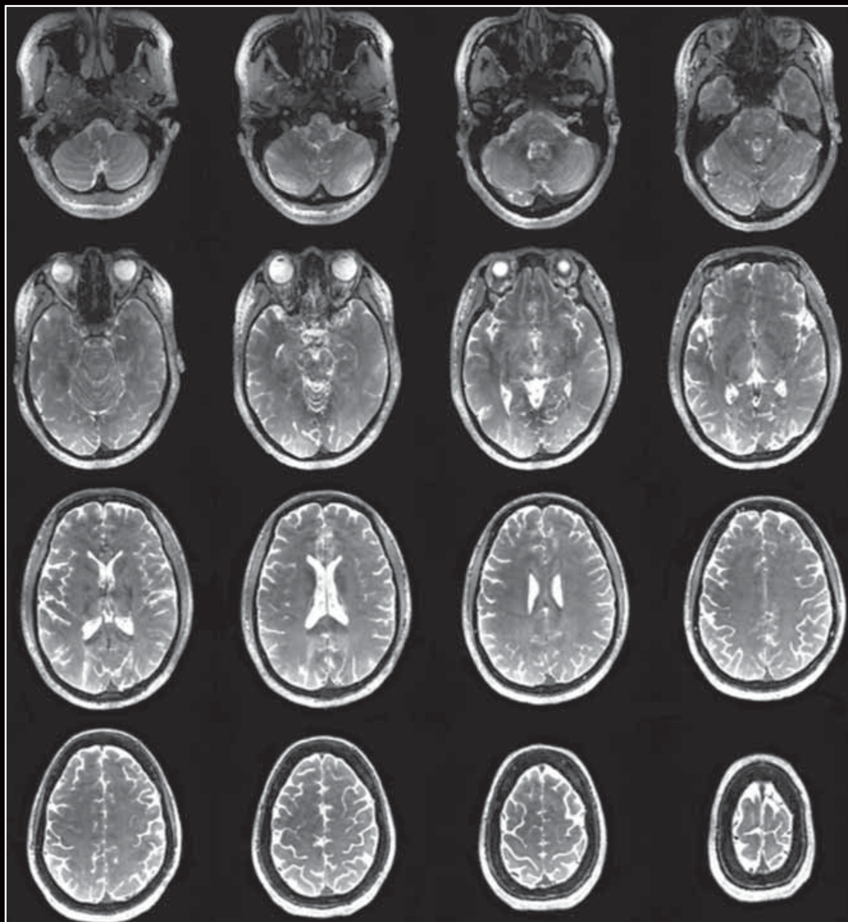
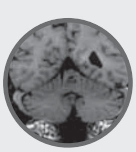


Figure 2. Whole-head T2 prepped MPRAGE at 7.0T MR at a spatial resolution of 1 mm isotropic. This shows the T2 prep module used in the Silent fMRI sequence generates flat T2 contrast throughout the brain, even in areas of high B_0/B_1 inhomogeneity.

To address this need, UCSF and GE Healthcare are working together to develop a Silent fMRI sequence. Barely audible above the background noise of the scanner, Silent fMRI may make the patient experience better, enable researchers and clinicians to study population subgroups where noise is a limiting factor, and allow the user to run experiments with auditory stimuli that were not previously possible due to the presence of noise.



Read more about ZTE MR neuro imaging in our special Neuro Summit Supplement, accessible through the SIGNA™ Masters website: www.gehealthcare.com/signamasters.

Zero Echo Time (ZTE) is the foundation for the Silent fMRI sequence development at UCSF. It is based on recent advancements in ZTE developed by Florian Wiesinger, Senior Scientist, and Ana Beatriz Sanchez, Scientist, at the GE Healthcare Applied Science Lab Europe (ASLE) in Munich, Germany. Wiesinger and Sanchez developed methods for ZTE that allow the creation of functional contrast with a T2 prep module. Using advanced image reconstruction and trajectory techniques enables a fast, quiet and quantitative scan that takes seconds to acquire the whole brain.

With the assistance of Brian Burns, Senior Scientist, at the GE Healthcare Applied Science Lab West (ALSW) in Menlo Park, CA, the ZTE developed by Wiesinger and Sanchez was modified for use on the GE 7.0T MR scanner at UCSF.‡ And, because the sequence uses an adiabatic T2 prep module, it doesn't suffer from the RF inhomogeneity problems that Dr. Larson experienced with other 7.0T MR acquisitions.

"7.0T intrinsically has a higher sensitivity and we added a T2 prep module that is tolerant to the swings in B_0 and B_1 fields," explains Dr. Larson. "So, by creating a robust prep module, we are very confident that the signal changes are due to physiology and not due to changes in B_0 and B_1."

‡ GE 7.0T MR systems are research only and not available for commercial sale.

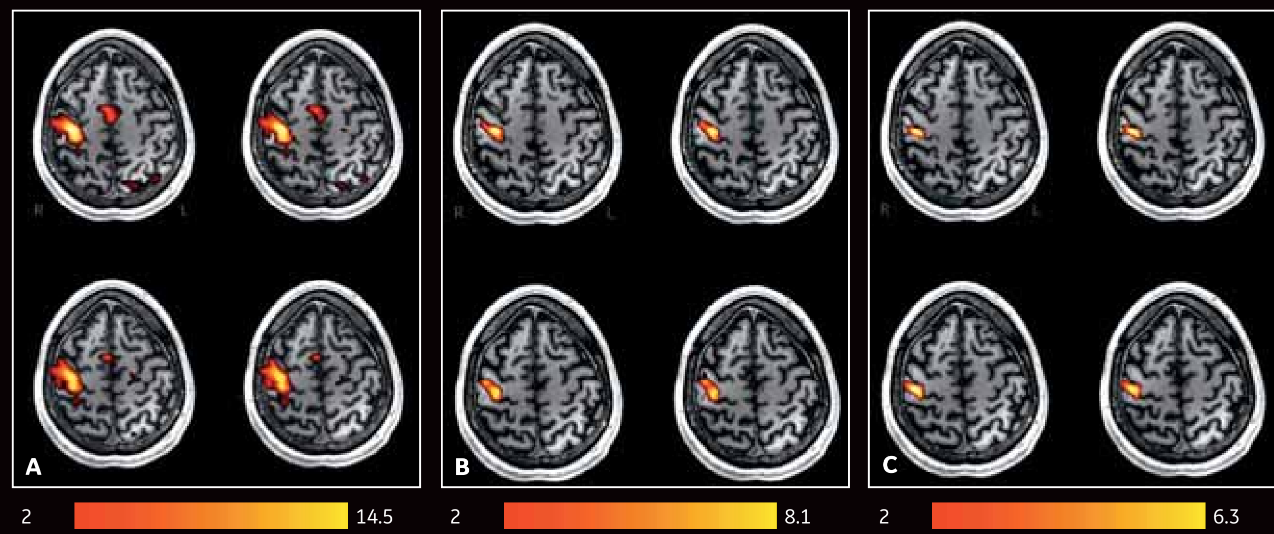


Figure 3. Left-hand squeezing task results for (A) Gradient Echo fMRI, (B) Spin Echo fMRI and (C) Silent fMRI for a single subject overlaid on an anatomical T1 image. As expected we're seeing spatial activations in the contralateral primary motor cortex in each of the methods. However, Spin Echo EPI and Silent fMRI show more specific localization to the cortex than Gradient Echo EPI.

In fMRI, it is the experiment that is often as important as the results. By removing the noise, Dr. Larson believes new opportunities for exploring the human mind will emerge. Resting state fMRI (rs-fMRI) is one such area where new experiments can be designed around the Silent fMRI technology to further expand clinical understanding of brain diseases.

While bringing this technology to 3.0T could be used more broadly, Dr. Larson says starting at 7.0T was a logical first step.

"By having the signal advantage of 7.0T, we can optimize the technique and conduct proof of concept studies," he says. "After we optimize the technique at 7.0T, then it should be easier to apply it to 3.0T for widespread usage." Colleagues at UCSF have been asking Dr. Larson for a 3.0T silent fMRI scan, demonstrating the importance of eventual translation to 3.0T.

One interesting aspect of Silent fMRI is that it doesn't place a lot of demands on the system capabilities like standard EPI acquisitions. It doesn't require the best gradients or RF coils, which may make it more available on a wider variety of lower-field MR systems.

Initial experiments using Silent fMRI have shown promising results. In one task-based experiment, the subjects would squeeze their left hand for 15 seconds, rest and repeat approximately nine times in a five-minute time span.

Early results demonstrate good contrast with T2 BOLD at 7.0T without the distortion that can occur at 3.0T. Dr. Larson sees a larger activation with the higher contrast at 7.0T, as expected, but also without the T2* BOLD contamination from large draining veins that is found in Gradient Echo EPI. Since Spin Echo EPI refocuses those T2* BOLD signals, it has less T2* BOLD contamination. Silent fMRI is more similar to Spin Echo EPI in that it provides a lower sensitivity but much higher specificity than Gradient

"We are seeing activation—spatial locations and sensitivity— in the right primary motor cortex that correlates with the same task results using Gradient Echo EPI and Spin Echo EPI sequences."

Dr. Peder Larson

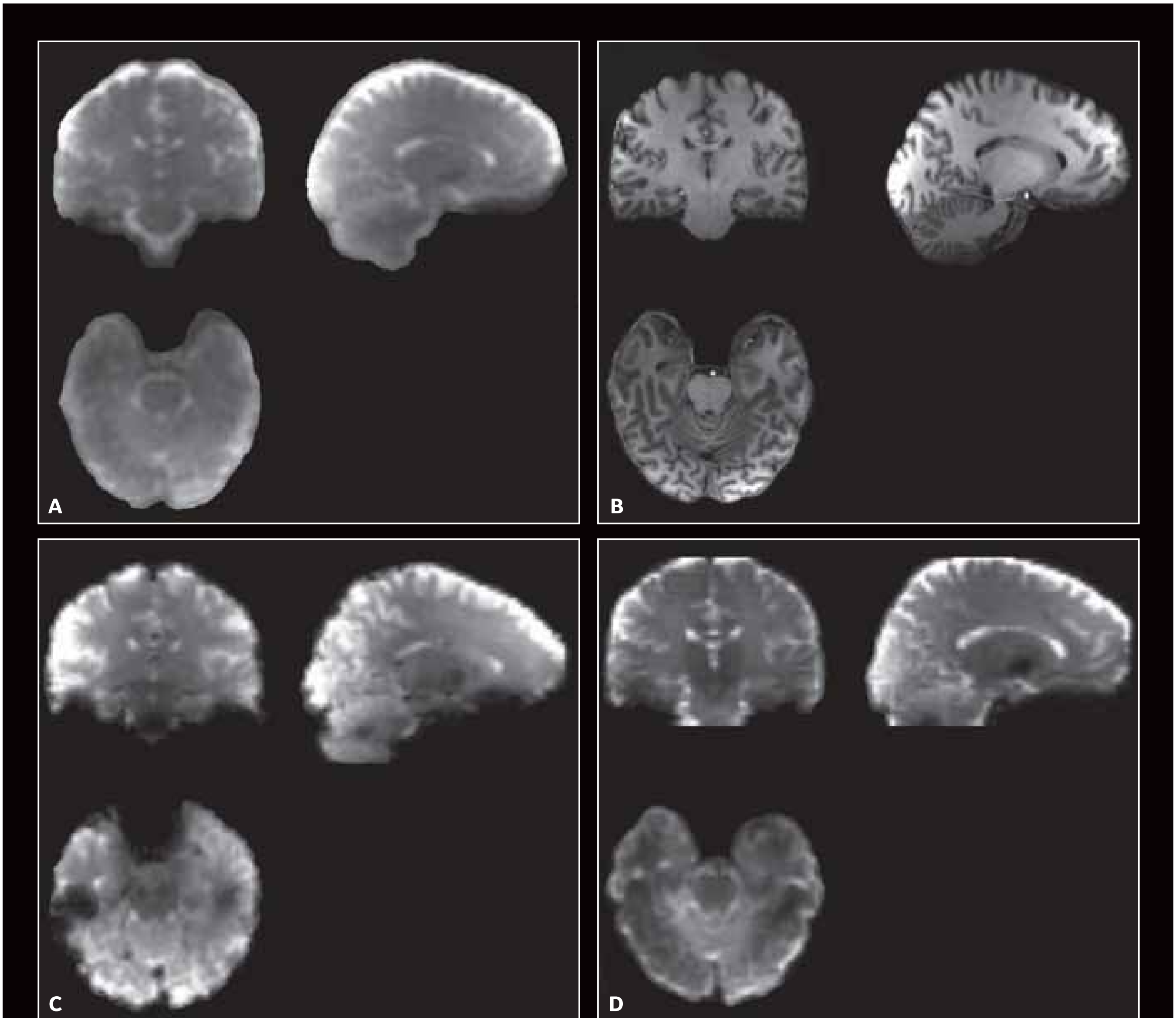


Figure 4. A comparison of (A) 3 mm isotropic Silent fMRI, (B) 1 mm isotropic MPRAGE, (C) 3 mm isotropic Gradient Echo EPI fMRI and (D) 3 mm isotropic Spin Echo EPI fMRI at 7.0T. There are no spatial distortions and signal dropout in the Silent fMRI, assuming the MPRAGE is the ground truth reference. However, there are significant distortions in the EPI-based methods.

Echo EPI. It is robust and not prone to artifacts due to the larger field inhomogeneities that can exist at 7.0T. "It's a small change", Dr. Larson says, "but a meaningful one."

UCSF, in collaboration with GE Healthcare, has just started an rs-fMRI experiment that images the subject for six to seven minutes while they lie on the scanner with their eyes closed. The goal is to identify the dominant resting state networks using Silent fMRI and then compare it to known networks imaged with Gradient Echo EPI to see if it matches.

Because the sequence is quiet, it can also be used to better understand the auditory system. For example, people who suffer from tinnitus, or a ringing in the ear, could be studied using Silent fMRI. These experiments could answer the key clinical question as to whether the noise is an issue in the ear or the brain. Another application is understanding which end of the sensory pathway is affected in these patients. Silent fMRI may be the first tool to help clinicians probe these questions. The same can be said for people suffering from schizophrenia or Lewy body dementia who often suffer from auditory hallucinations.

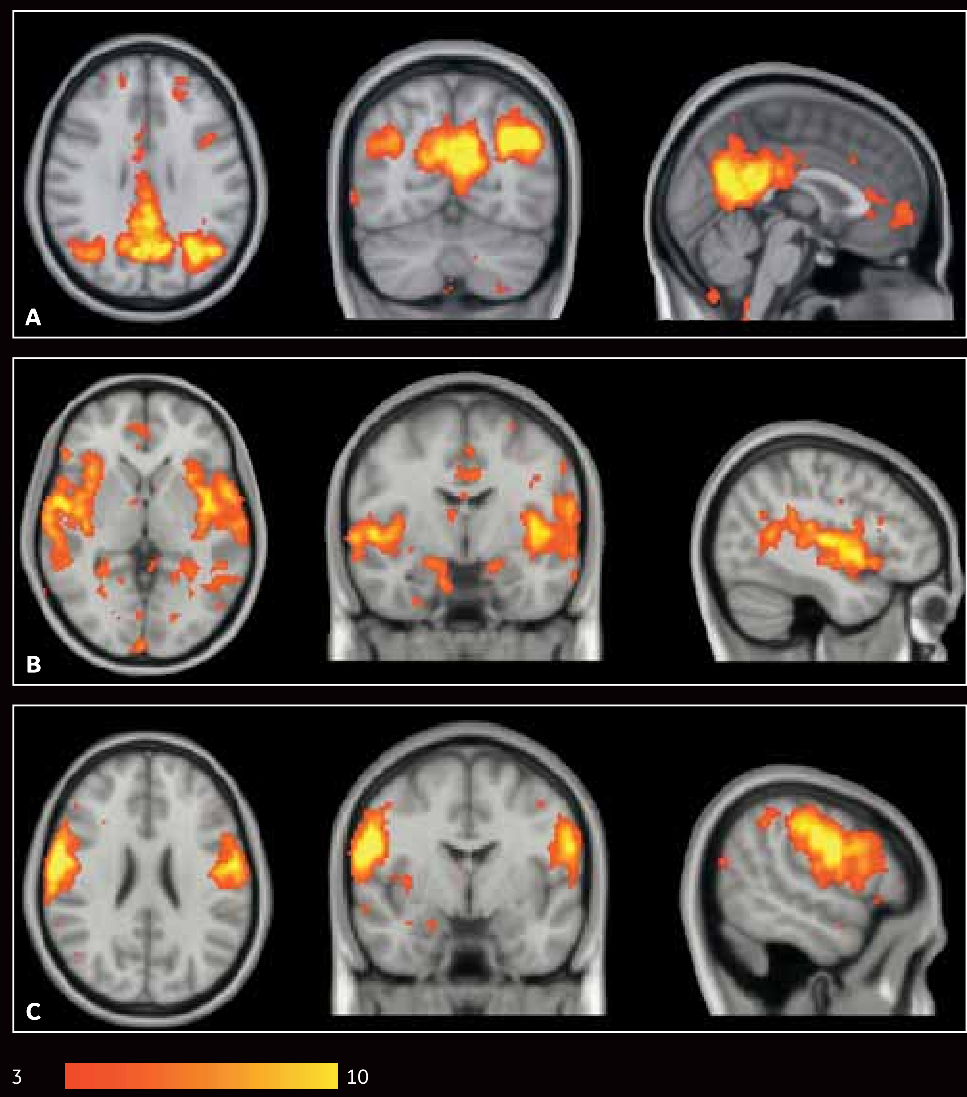


Figure 5. Resting state network results for the Silent fMRI method taken from seven subjects. (A) Default Mode Network (DMN), (B) Primary Auditory Network (PAN) and (C) Sensory Motor Network (SMN). The (A) DMN images look good, while the (B) PAN contain some insula, which is normally not part of the auditory network, and the (C) SMN contains some lateral prefrontal cortex.

"Every time I talk to other researchers about this technique, I hear a new idea about where this sequence could be useful. People in this field expect noise to be a confounding factor for fMRI experiments, and they get very excited when they see how Silent fMRI transforms the experiment by removing noise."

Dr. Peder Larson

Each element in our AIR Technology™ Coil is formed with breakthrough conductor loop technology. Lightweight and flexible, it's the core of the industry-leading, form-fitting coil design elevating the patient experience. It's new engineering that provides superb SNR and acceleration performance to meet your ever-changing clinical needs. Not only is it the backbone of AIR Technology™, it will shape innovation in coil design for years to come. **Learn more at gehealthcare.com/mr.**

AIR Technology™ is not available for sale in all regions.

© 2018 General Electric Company – All rights reserved.
GE, the GE Monogram and AIR Technology are trademarks of General Electric Company.

MR-0511-11.18-EN-US
JB62025XX