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Welcome

I would like to take this opportunity to introduce myself as the new President and CEO of GE Healthcare’s MR business. I am truly honored and humbled to be returning to MR as its business leader and am excited to meet many new faces and reconnect with familiar ones in this role.

My career with GE began 30 years ago in engineering; developing satellites and satellite ground stations in GE Aerospace. I joined GE Healthcare in 1996 as part of the MR engineering team and in 1998, was promoted to lead this team.

After roles in Genomics, Molecular Imaging and CT—and most recently leading the MICT business—it feels great to return home to MR.

I can assure you the vision for MR hasn't changed. We are focused on you, our customers, understanding your needs and delivering the most innovative solutions to enable your success.

The Return of SIGNA

In 1983, SIGNA™ changed the course of MR history with the industry’s first 1.5T MR system, the SIGNA™ 1.0. This year, SIGNA will once again be rewriting the rules of MR. And I am excited to share with you some of the revolutionary products we are launching at RSNA.

For 30 years, the name SIGNA embodied innovation, proven quality, and trust. And SIGNA still maintains the highest awareness among our products. Just as GE Healthcare revolutionized MR with the SIGNA brand in 1983, we once again plan to revolutionize the future of our business with completely redesigned advancements in MR technology and practice. We are excited for you to see our return to SIGNA at RSNA this year with the introduction of several new products and innovative solutions across our portfolio.

SIGNA PET/MR†

The first member of our new SIGNA family, the SIGNA™ PET/MR, not only symbolizes the return of the SIGNA brand name, but it also features Silicon Photomultiplier (SiPM) technology never seen before in conventional PET technology. The SIGNA PET/MR is the industry’s first integrated PET with pioneering time-of-flight (TOF) technology and exceptional quantitative count rate accuracy combined with leadership 3.0T MR for simultaneous imaging. The result is exceptional PET sensitivity. It provides sharper image quality, precise attenuation maps, an active and passive thermal control and an intuitive workflow to provide stability for the most demanding protocols.

DV25.0 Continuum Pak

We’re also excited to launch our new software package, the DV25.0 Continuum™ Pak. This software is designed to bring advancements in both patient comfort and technology to meet the latest diagnostic trends and applications to address challenges unique to today’s clinical environment.

The DV25.0 Continuum Pak features SilentSuite, allowing for an entire neurological exam (including diffusion) to be conducted at near ambient levels. Conventional MR scanners can generate noise in excess of 110 decibels, roughly equivalent to the noise at a rock concert; with SilentSuite, all routine exams can be conducted at noise levels that are 3db(A) to 11 db(A) above ambient.

The software features don’t end there. They also include:

• DISCO, an application that changes the paradigm for body imaging through a unique, high-temporal and spatial resolution approach in a short scan time;
• MAVRIC SL 2.0, an application designed to meet the needs of an aging population with the ability to image around MR Conditional implants and;
• Turbo LAVA, an application that addresses the need for multiple high-resolution arterial phases in a single breath-hold in body imaging.

With products like these, and others we’ll introduce at RSNA, there’s no doubt in my mind that this will be our RSNA.

As you read through the pages of this issue, I hope you share the passion that I feel for innovation. If you’re coming to RSNA, please make sure to stop by our booth to imagine—and see—what MR can be.

Eric Stahre
President and CEO
Global MR, GE Healthcare

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

GE’s 10,000th Magnet Milestone: So Much More Than Technology

A dedicated magnet team made it possible to scan more than 175 million patients and produce 5 billion high-quality MR images.

When you think about an MR scanner, what comes to mind? For many, it’s technology. And what makes that technology work? The magnet is obviously a critical component. Without the magnet, an MR system is lifeless. But to make one stand the test of time, it takes a dedicated team of professionals that meets specifications time and time again.

GE Healthcare’s Florence, SC magnet facility team—which has designed and manufactured superconducting magnets for more than 30 years—performs at the highest level day in and day out. And here’s the proof: In September of 2014, the group waved goodbye and shipped the 10,000th Low Cost Cryostat (LCC) magnet to Morris County Hospital in Council Grove, Kansas.

The magnet type was the first in the industry to reach 10,000 units produced—a sign of its reliability and high quality. The LCC has been used in more than 10 different GE MR systems since it was first produced in 1998, and it’s currently used in scanners such as the Brivo™ MR355 Inspire and the Optima™ MR360 Advance. It will be featured at RSNA as part of GE MR’s new value segment launch. Interestingly, GE will mark the 10,000th milestone while RSNA celebrates its 100-year anniversary.

Insight...

GE’s first MR scanner was built in the Florence, SC plant over 30 years ago. Since that launch, the site has designed and built over 15,000 superconducting magnets at field strengths from .5T to 3.0T.
Attracted to innovation

In 2013, GE Healthcare MR raised a glass to 30 years of groundbreaking innovation. The 10,000th magnet milestone is now among a long history of MR achievements and scientific firsts. (To read about them, visit tiny.cc/spa143).

The LCC magnet was first prototyped in 1996 as a joint GE Global Research Center (GRC) and GE Healthcare project. The businesses were researching a cost-efficient magnet design for customers. At the time, GRC was working on a Low Cost Cryostat technology and the Florence magnet team was developing the first Zero Boil-Off technology. The entities combined concepts, and in 1997, the first LCC magnet was produced. Shortly thereafter, the sixth LCC magnet was the first to be used in a clinical site in North Platte, Nebraska at the Great Plains Regional Medical Center.

"Reaching this milestone tells us that the magnet is solid, reliable, and our customers like it. It was the first Zero Boil-Off technology in the industry, which greatly saves costs for MR customers because the magnet doesn't lose helium in normal operation," says Bill Chen, former GE Healthcare Program Manager for the LCC magnet. "I am extremely proud of the innovative magnet and the benefits it brings to the entire MR industry and our customers."

It is conservatively estimated that more than 175 million exams have been conducted on the 10,000 magnets and more than 5 billion images have been produced to help clinicians diagnose diseases. This equates to approximately 3 billion hours of scanning time. One reason that the LCC was the first to reach the milestone is the unique advantage of the GE MR Continuum™ strategy. “Customers can keep their magnet and upgrade features to stay current with the latest GE technology. This Continuum approach greatly protects the customer’s investment. Plus, the LCC is very cost competitive with low quench rates,” offers Chen. See page 11 to learn about the new DV25.0 Continuum™ Pak.

The heart of the milestone

The 10,000th achievement can also be largely attributed to the 350 hard-working GE magnet employees in Florence, who boast an average tenure of more than two decades with the company. "More than 175 million patients worldwide have received high-quality MR care due to the team’s loyal work," comments Peter Jarvis, Chief Engineer of MR Magnets at the Florence plant. “Some may say that the magnet is the technological heart of an MR system, but this accomplishment goes far beyond technology. Dedicated people are what made the difference.”

Jarvis continues, “All of the LCC magnets were built in Florence, and since the beginning, the team has taken pride to assure that each and every magnet was made to the same specifications to provide customers with reliable MR images.”

One such team member is Mike Creel, currently a second shift Lead Technician with special responsibilities for leak testing. Creel joined GE, Florence in 1977, when it was a Mobile Radio plant, as an Assembler. He transferred to MR one year after the operation started, when there were only 75 employees, assembling many of the early SIGNA™ magnets. Also, Creel helped the MR team develop a smaller, lighter-weight magnet—resulting in the Conquest magnet. Concurrently, the MR team was developing Zero Boil-Off technology with a Low Cost Cryostat when, combined with the Conquest magnet, the 1.5T LCC magnet was born. Creel personally worked on building LCC magnet number nine as a Process
Standing the test of time

GE customers are also pleased. “The Optima MR360 Advance is what we really wanted and now that it is here and being installed, it’s a dream come true,” says Greg Welle, Partner at Manhattan Radiology, LLP and Staff Radiologist at Morris County Hospital. “To find out that this is GE’s 10,000th magnet in this line is a nice surprise. It reaffirms that we are getting technology that has been tested and refined many times over. We certainly have lots of confidence in the magnet moving forward and are proud to share this milestone with GE.”

Corky Messer, Radiology Director at Morris County Hospital, concurs. “When we received word that we had purchased GE’s 10,000th magnet, it confirmed that we bought a magnet that would stand the test of time.”

Insight...

GE invested $17 million to build a 5,000 square-foot facility in Florence, SC—located next to the magnet plant—that captures and recycles pure helium gas, then compresses it into a liquid that’s essential to MR production. GE is also working on new magnet designs and innovative cooling techniques that are less dependent on helium.

At a Glance: GE Healthcare in Florence, SC

- GE Healthcare has a 30-year history in Florence, SC, and is Florence County’s 7th largest industrial employer.
- The Florence MR magnet production facility is around 500,000 square feet and has 350 GE employees (welders, technicians, assemblers, engineers), with an average tenure of more than two decades with the company.
- GE Healthcare Florence employees volunteered approximately 3,600 hours in 2012 locally.
- GE uses 730 unique parts from 120 suppliers to manufacture each magnet.
- Approximately one-third of the world’s superconducting MR magnets are now manufactured in Florence.
GE Healthcare and UK-based Tesla Engineering Ltd. are collaborating on the development of an investigational 7.0T\(^{1}\) magnet. The alliance builds on GE’s 10-year history of producing 7.0T MR scanners, currently used in the US, Italy, and Japan for medical and scientific research, primarily in morphological and functional imaging of the brain. Tesla is building a new facility in Storrington, Sussex, England to produce the powerful magnets for these scanners.

In the US, four GE 7.0T scanners are installed—one each at Stanford University; the University of California, San Francisco; the Medical College of Wisconsin (MCW); and another is currently being installed at the University of Iowa (U of I). Additionally, a facility in Lublin, Poland has an agreement with GE to install one.

Here’s an update on two of the US sites: MCW’s 7.0T scanner with an Active-Shield magnet is designated for cutting-edge neuroscience research and was recently moved into a specially built addition to the MR research facility. The scanner is a shared resource that offers ongoing research collaborations among investigators from many departments at MCW, and it encourages new collaborative studies within MCW and with other institutions.

“Ultimately, this research will move scientific discoveries forward and potentially benefit patient care. MCW is very pleased to have this opportunity to extend our relationship with GE with this advanced technology,” comments Professor Shi-Jiang Li, Director of the MCW Center for Imaging Research and leader of the 7.0T initiative at MCW.

GE Healthcare and the U of I recently announced their collaboration on 7.0T MR, with special focus on brain and musculoskeletal physiology research. In October, 2014, the Pappajohn Biomedical Discovery Building was the site of a dedication and ribbon cutting ceremony.

“The new 7.0T system will produce high-resolution images of microscopic structures within the human body and be used for research,” says Vince Magnotta, PhD, Associate Professor and Principal Investigator of the 7.0T project at the U of I. “Our 7.0T research plans include functional brain imaging, diffusion tensor imaging, anatomical imaging, molecular imaging, cartilage and soft tissue assessment, and tumor imaging and treatment planning.”

\(^{1}\) Investigational device not commercially available. Limited by law to investigational use in compliance with applicable local ethics and research requirements.

“Ultimately, this research will move scientific discoveries forward and potentially benefit patient care.”

Professor Shi-Jiang Li
GE Shares WMIS Gold Medal for Hyperpolarized MR

At its 2014 annual meeting in Seoul, Korea, the World Molecular Imaging Society (WMIS) presented its prestigious Gold Medal Award jointly to Klaes Golman and Jan-Henrick Ardenkjær-Larsen (GE); Sarah Nelson, John Kurhanewicz, and Dan Vigneron (University of California San Francisco); and Kevin Brindle and colleagues (University of Cambridge). The medal is for pioneering work in the field of DNP-induced hyperpolarized MR.

GE Healthcare dedicated $1 billion of its total R&D budget to expand its advanced cancer diagnostic and molecular imaging capabilities, as well as its world class technologies for the manufacture of biopharmaceuticals and cancer research. The company is a leader in diagnostic imaging.

"In MR, this reinforces our focus on the development of technologies such as metabolic imaging with hyperpolarized Carbon 13\textsuperscript{1} for research activities," says Jonathan A. Murray, Managing Director of GE’s Research Circle Technology, Inc., which aims to create a strong alliance between GE’s scientists and the world’s leading universities. “We are proud of our global collaborations that further accelerate and help enhance the development of metabolic imaging, including the C13 technique for the first human studies at UCSF."\textsuperscript{5}

Former Apple Evangelist Speaks at Customer Event

Of special interest to conference attendees was GE’s Customer Event, which attracted more than 400 guests. At the event, Guy Kawasaki, former Chief Evangelist for Apple, spoke about innovation and leadership. The customer event received high praise from attendees. Highlights of Kawasaki’s presentation included advice for staying one step ahead; for example, by anticipating customers’ needs—which is the key to all innovation, and "jumping to the next curve"—which is where true innovation occurs.\textsuperscript{5}

At the 2014 ISMRM conference in Milan, Italy, GE Healthcare made key announcements including its reinforced commitment to 7.0T MR (see previous page) and alliance with CorTechs Labs to sell the NeuroQuant\textsuperscript{8} MR post-processing application. NeuroQuant performs automatic measurements of cortical and subcortical volumetric brain images to measure neurodegeneration.

Additionally, GE’s Research Circle Technology, Inc.—launched in 2011 to enhance development of innovative technology in collaboration with leading scientists—announced its first product. SPINlab\textsuperscript{9} is a hyperpolarizing system\textsuperscript{11} that has research potential in the visualization of metabolic activity at the cellular level using MR imaging.

\textsuperscript{1} Output of this equipment may only be used for human applications under an approved research study (IND or equivalent). SPINlab is not a medical device.

NeuroQuant is a registered trademark of CorTechs Labs.
All other trademarks are the property of General Electric Company.
GE Healthcare announces the new Orchestra Software Development Kit (SDK)† to help customers develop novel reconstruction algorithms in less time. The Orchestra SDK provides collaborators with direct access to GE’s commercially available reconstruction routines instead of developing code from scratch.

For example, it allows users to call the exact same routines that are utilized in GE’s product MR reconstruction code to write images in DICOM format, phase correct data (FSE and EPI), orient images in radiological coordinates, use GE’s parallel imaging routines, and insert images into the scanner database through standard interfaces using Matlab or C++. The Orchestra SDK includes reconstruction templates and online help to get users started and it is available through a new collaboration portal created for customers using GE MR scanners.

“The collaboration portal was motivated by the release of the Orchestra SDK with a research approach, and it was tailored for use by our academic partners,” offers Jeff Hopkins, Senior Software Architect at GE Healthcare. “It gives them a way to contact us and connect with each other about the Orchestra SDK and other collaborative efforts.”

The online collaboration portal, https://collaborate.mr.gehealthcare.com, is the primary way users can obtain the Orchestra SDK and then engage collaboratively with other customers and representatives at GE. The interactive portal is open to anyone with a GE MR system.

“The Orchestra SDK is our first reconstruction development kit, and the collaboration portal—which makes it easy for users to connect—is a huge step forward for GE MR. It will serve as a gateway for GE’s internal development and represents an important advancement toward furthering collaboration with our luminary partners,” says Hopkins. S

GE Healthcare is pleased to announce the appointment of John Flannery as its new president and CEO. Flannery, 53, most recently served as senior vice president of business development for GE. Over the last year, Flannery led business development activity related to the purchase of Alstom’s energy and transmission businesses, the spinoff of Retail Finance, and the sale of GE Appliances. Prior to that, Flannery was the president and CEO of GE India and a senior leader at GE Capital.

“With 27 years of experience across GE corporate, GGO and Capital, John has a track record of growing businesses with a special emphasis on global expansion,” says GE Chairman and CEO Jeff Immelt. “He has a deep understanding of GE’s industrial businesses and strategy. He’s the right person to lead the next chapter at GE Healthcare.” S

† Orchestra SDK is not a medical device and not intended to treat, diagnose, nor cure any disease or condition.
GE’s New DV25.0 Continuum Pak Recharges the MR Experience

Continuum is anything that goes through a gradual transition from one condition, to a different condition, without any abrupt changes. With the new DV25.0 Continuum™ Pak from GE Healthcare, clinicians can smoothly upgrade to leading MR advancements while expanding their commitment to patient care. However, customers report that the results of their DV25.0 Continuum Pak upgrade are anything but gradual. Here’s a look at some of the key new features.
In order to reduce artifacts typically caused by inhomogeneous fat suppression common in current 4D applications, DISCO uses a two-point Dixon fat-water reconstruction algorithm. “This is a game changer because DISCO redefines the paradigm for body/oncology imaging through a unique, high-temporal and spatial resolution approach in a scan time not previously possible. The high-resolution FOCUS images help delineate lesions thanks to a reduction in distortion and robust fat suppression. PROPELLER assists with minimizing breathing motion artifacts in T2w imaging.”

Make a move with DISCO

DISCO (Differential Sub-sampling with Cartesian Ordering) is a key application of the new DV25.0 Continuum Pak. It uses a dual-echo 3D SPGR sequence with pseudo-random variable density k-space segmentation and a view-sharing reconstruction to achieve high spatio-temporal resolution. DISCO samples an elliptically ordered central k-space region every temporal frame, and sub-samples the outer regions in a pseudo-random fashion to improve motion and aliasing types of artifacts.

According to Daniel Moses, MD, a radiologist at Spectrum Medical Imaging in Sydney, Australia, “It’s apparent that contrast resolution of DISCO really adds a lot of value for early perfusion characteristics in prostate tissue.” Beyond prostate, where temporal resolution is seen to play the greatest role, DISCO allows for a significant increase in spatial resolution, important for breast DCE imaging. Francois D’Anthouard, MD, a radiologist at GIE IRM in Creil, France, says, “DISCO opens up incredible opportunities for increasing the spatial resolution of DCE breast imaging.”

In order to reduce artifacts typically caused by inhomogeneous fat suppression common in current 4D applications, DISCO uses a two-point Dixon fat-water reconstruction algorithm. “This is a game changer because DISCO redefines the paradigm for body and oncology imaging through a unique, high-temporal and spatial resolution approach in a scan time not previously possible,” says Mark Stoesz, Global Premium Marketing Manager with GE Healthcare. “It rapidly generates time-resolved 4D images to meet the challenge of multidynamic imaging, offering high-resolution volumes of 1.5 mm in four seconds or less.”
“We are enormously proud of the fact that we are the only healthcare company able to offer ‘head to toe’ imaging at near ambient levels,” comments Stoesz. “As part of our commitment to helping customers take MR to the next level, those who purchased SilentScan with the DV24.0 Continuum Pak will automatically receive SilentSuite when upgrading to DV25.0.”

**Head to toe with SilentSuite**

Available on the Discovery™ MR750w and the Optima™ MR450w with GEM, the DV25.0 Continuum Pak allows facilities to revitalize their commitment to patient care by bringing leading advancements in comfort to their clinical offering. “Sometimes, all it takes is a spark to inspire a whole new era of growth. The DV25.0 Continuum Pak is just that, providing leading advancements in patient comfort, the technology to meet the latest diagnostic trends, and the applications to address challenges unique to today’s clinical environment,” states Stoesz.

SilentSuite, GE’s latest advancement in MR noise-reduction technology, has the ability to transform a patient’s MR experience—delivering an entire neuro exam, now including diffusion, at near ambient levels.

Other anatomies have been added to the list, so routine exams can be performed at less than 11dB(A) above ambient. And with SilentScan, Zero-TE can potentially provide results with considerably reduced susceptibility related artifacts.

“Turbo LAVA images look like CT images, with the benefit of MR contrast.”

*Dr. Mark Zins*
Strengthen clinical capabilities

Being strategic about clinical imaging requires having the foresight to revitalize the way clinicians image today, so they are prepared for the imaging trends that will define the future of MR. “The DV25.0 Continuum Pak is designed to provide facilities with key technologies to strengthen their clinical capabilities, in order to accelerate their next diagnostic move,” says Stoesz. In addition to DISCO and SilentSuite, here’s a snapshot of other applications the upgrade has to offer:

- MAVRIC SL 2.0 allows clinicians to meet the needs of an aging population with the ability to image around MR Conditional implants. MAVRIC SL 2.0 delivers multiple contrasts, now including T1, allowing for improved visualization of tissue close to MR Conditional implants. Suresh Kumar Dalavaye, MD, a radiologist at Morristown Hospital, Swansea, Wales, UK, says, "MAVRIC SL 2.0 is an excellent sequence to assess the metal bone interface."

- Turbo LAVA provides as much as 40% reduced breath-hold times compared to the conventional techniques, allowing for multiple high-resolution arterial phases in a single breath-hold. “Turbo LAVA images look like CT images, with the benefit of MR contrast,” offers Marc Zins, MD, Director of Medical Imaging Services, St. Joseph Hospital in Paris, France.

- Cube DIR provides an enhanced ability to suppress white matter and delivers improved conspicuity due to this suppression of white matter tissue. According to Stoesz, neuro imaging continues to grow along with the need to better visualize white matter diseases. Jerome Hodel, MD, a radiologist at St. Joseph Hospital in Paris, France, concurs. “We find the CubeDIR sequence is suitable for the assessment of cortical or juxta cortical lesions due to the suppression of subcortical white matter.”

- With MDE PLUS, facilities can easily expand their cardiac imaging capabilities with high-resolution, whole heart, single breath-hold delayed enhancement imaging results. Additionally, fat suppression can be applied to standard MDE. “MDE PLUS helps us obtain more reliable and producible results... we are now able to examine challenging patients with single shot MDE,” concludes Jean-Louis Sablayrolles, MD, a radiologist at Centre Cardiologique du Nord in Saint-Denis, France.

- IDEAL IQ WITH ARC delivers unique information regarding fat infiltration within the liver. By combining ARC and IDEAL IQ, clinicians can reduce the breath-hold or increase spatial resolution.

- The new MR Touch algorithm can provide an increase in productivity through faster processing and improved image visualization.

In addition, the DV25.0 Continuum Pak includes GEM Flex positioners, which embrace patient anatomies to potentially reduce pressure points and speed scan set-up times. Combined with new productivity enhancements such as eXpress Prescan, the GEM Flex positioners help to reduce table time for patients.
Breathe life into workflow

According to Stoesz, in order to meet today’s productivity demands, GE Healthcare listened to its customers and developed a strategic set of workflow enhancements to accommodate higher patient volumes and an increasingly diverse range of patient and operator situations. “The DV25.0 Continuum Pak reduces pre-scan set up times by as much as six minutes with the new automating procedures. It also takes the guesswork out of more complicated procedures with new linking and copy/paste enhancements for protocol creation.” Additionally, because the GEM Flex coil positioners help accommodate most patient sizes, facilities receive the advantages of rigid coils without their limitations. This can equate to easier set up and less patient movement during an exam.

The DV25.0 Continuum Pak provides clinicians with the opportunity to imagine what MR can be. From shaking it up with DISCO to keeping it virtually silent with SilentSuite, the upgrade helps ensure that their future with MR is bright. “DV25.0 is all about recharging the MR experience, sparking a new future of growth, expanding commitment to patient care, defining the next diagnostic move, and empowering clinical performance,” concludes Stoesz.

“DV25.0 is all about recharging the MR experience, sparking a new future of growth, expanding commitment to patient care, defining the next diagnostic move, and empowering clinical performance.”

Mark Stoesz, GE Healthcare
Clinicians Across China Demonstrate MR Leadership in Practice and Science

By Zhenyu Zhou, PhD, MR Research China Manager and MR Advanced Applications Manager, GE Healthcare China

With a population of more than 1.35 billion people and, in 2013, the world’s second largest economy, China has a rapidly growing need and the economic sources for advanced healthcare products, including MR. The country has undergone rapid modernization and urbanization in the last 20 years and today Shanghai—China’s largest city with 22 million residents—has the 25th largest city GDP in the world, totaling US $304 billion in 2011.1

A recent healthcare provision initiative by the Chinese government2 has led to approximately 95% of the population having basic health insurance coverage.3 Most healthcare in China is privatized, which has also resulted in increased quality as well as higher demand for healthcare services.

Today, China is investing heavily in scientific research and development of cutting-edge technology such as high-field (3.0T) MR and specific applications such as fMRI. Over the last 10 years, many clinicians in China have been conducting MR research.

**MR across a wide geography**

GE Healthcare MR collaborates with over 50 clinical facilities in China, covering many top-level hospitals. It is in Beijing where the greatest proportion of research activities occurs, such as PLA 301 and Peking University affiliated hospitals. These institutions are the leaders in many research areas.

For example, Peking University has two GE scanners that it utilizes for MR technique development. The site’s research leader, Professor Jiahong Gao, a former director of the MR research center at the University of Chicago, leads a strong group of researchers who focus on fundamental MR physics and conduct research. Areas include neuro-current detection and new diffusion imaging modeling.

In the North, Tianjin is second to Beijing in terms of clinical research collaboration. Tianjin Medical University General Hospital (TMUGH) is the cradle of modern radiology in China and has an excellent reputation throughout the Chinese MR community. Professor Chunshui Yu, Dean of the Department...
of Radiology at TMUGH, is a renowned radiologist specializing in MR novel techniques of the central nervous system, abnormal activities of brain sub-regions, and neurodegenerative diseases.

Neuroscience research also plays an active role in clinical hospitals and research institutes in the Eastern region of China. For example, at Zhejiang University, the second Affiliated Hospital and one of the largest hospitals in Eastern China, the hospital's focus is on neurodegenerative diseases. Buoyed by more than $1 million RMB from China's National Science Foundation, the hospital's projects include utilizing MR imaging to measure brain perfusion.

Dr. Xuchu Weng from Hangzhou Normal University is one of the pioneers conducting functional MRI (fMRI) research in China, going back almost 20 years. Also from Hangzhou Normal University is Dr. Yufeng Zang, a leader in the resting-state fMRI field. Together, they received $40 million RMB funding and selected a GE 3.0T scanner as their dedicated research platform. Their current projects include the investigation of high frequency components of BOLD signal in resting-state fMRI using multiband EPI.

In Shanghai, the 100 year-old Ruijin Hospital is one of the most prestigious hospitals nationwide. Clinicians at the hospital are focused on neurodegenerative diseases and amnestic mild cognitive impairment (MCI).

Renji Hospital is another leading hospital located in the Eastern region with an emphasis on pediatric populations. Dr. Yan Zhou, and her colleagues discovered perfusion changes in adolescents with internet gaming addiction (IGA).

In the South China city of Guangzhou, multi-center research is being conducted under the direction of Professor Weng Jianping, Vice President of Sun Yat-Sen University Third Hospital. His aim is to quantify the fat content of liver and other abdomen organs in patients with both type II diabetes and non-alcoholic fatty liver diseases (NAFLD). There are 10 participating hospitals in this study.

In the rural geography of Western China, Professor Jian Yang and his colleagues from the first affiliated hospital of Xi’an Jiaotong University are analyzing differences in DTI parameters between normal and mild hypoxic-ischemic (HI) pediatric brains. Finally, Professor Dapeng Shi’s group from Henan People’s Hospital is conducting an innovative research project using real time fMRI neurofeedback. He hopes to better understand the mechanisms for controlling pain perception levels to help patients with severe, chronic pain.

Demographics drive clinical research

Throughout all of China, an aging population has driven an increased focus on the management of neurodegenerative diseases. Clinicians are reporting that MR may hold promise for being an important tool in evaluating perfusion changes and...
increased or decreased cerebral blood flow in patients. For example, Dr. Bei Ding, and her colleagues from Ruijing Hospital found perfusion abnormalities in patients with neurodegenerative disease or mild cognitive impairment.

Professor Gao’s group at Peking University has taken the lead of MR physics research, devoting a significant part of his research career on functional MR studies. Already a well-established scholar in this field, he is now breaking into a new research field of brain functional imaging that he hopes will overcome the intrinsic limitations of the widely accepted BOLD technique, which may open a new era for studying brain function.

DWI has become an indispensable tool for research around early detection of acute cerebral ischemia and brain diseases, such as neoplasms, infections, and traumatic injury. Professor Xiaoying Wang’s group at Peking University First Hospital is investigating combining DWI with MR Spectroscopy in an effort to overcome the inability of DWI to distinguish the extracellular water diffusion coefficients from the intracellular ones. With the higher field strength and more powerful gradient systems of new MR scanners, it is likely that there will be more research focused on diffusion imaging.

Continued changes in eating habits, such as increased adoption of Western foods, coupled with an aging population has led to an increase in cardiovascular disease across China. Approximately 230 million Chinese people suffer from cardiovascular diseases with a mortality rate of 3.5 million. According to the World Health Organization (WHO), these numbers are expected to increase 50% between 2010 and 2030 based on the aging population in China.5

While CT and CT Angiography remain the imaging modality of choice for minimally-invasive evaluation of cardiology patients, there are several sites across China researching the utilization of cardiac MR techniques.

One of the most common chronic liver diseases in the world is NAFLD. The prevalence of NAFLD across all ages in China is 15%; in children, the median rate of 2.1% skyrockets to 68.2% among those who are obese.6

Fatty content in the human body is a critical indicator of certain diseases and is often evaluated in treatment follow-up for tumor management.

Beyond the traditional fat suppression typically applied in an MR exam, direct fat content quantification has recently become more prevalent in clinical MR.

The gap between lab development and clinical practice is where many clinicians across China see the value of supporting the type of studies outlined in this article. GE Healthcare MR, China is committed to providing the advanced technology needed to continue advancing research across this great country.

References
In Diffusion Weighted (DW) MR, molecular diffusion effects are encoded by magnetic gradient field pulses. The technique produces MR images with diffusion dependent signal loss/attenuation.¹ During their random walk, water molecules probe the tissue organization at a microscopic scale way beyond the MR imaging resolution, which previous studies have shown make DW MR a very powerful tool² for detecting/monitoring tissue micro-structural changes associated with development, degeneration, cancerous growth, and other disease states. Diffusion Tensor Imaging (DTI) provides even more structural insight by characterizing the anisotropy of molecular diffusion as described in this comprehensive technical review.³ Given the tremendous potential, it is no surprise that DW MR is being increasingly adopted in routine clinical exams.

However, obtaining diagnostic quality DW MR images with adequately high spatial resolution consistently still remains a technical challenge, especially in anatomies outside the brain. Single shot Echo-Planar Imaging (ssEPI) is favored for diffusion imaging because of its k-space traversal speed and high signal-to-noise ratio (SNR) efficiency. But its drawback is the long readout during which it experiences T₂* decay and cumulative phase errors from off-resonance (B₀ inhomogeneity, susceptibility gradients, eddy currents, chemical shift, etc.) that manifest as blurring, distortion, and ghosting in MR images. Techniques such as parallel imaging and segmented EPI⁴–⁷ can be used to shorten the echo-train length (ETL) and reduce phase-errors, but these have their own associated artifacts, especially in the presence of motion. An alternative approach would be to employ reduced field-of-view imaging (rFOV).
A majority of the organs in the body where diffusion weighted imaging (DWI) is applied, such as the spinal cord, prostate, or pancreas, are small in size compared to the size of the torso. So the idea of reducing the FOV and “focusing into” the region of interest would make perfect sense. With conventional radio-frequency excitation that has spatial selectivity only in the slice direction, the entire subject FOV extent in the phase direction has to be spatially encoded during signal reception to prevent mis-registration of excited frequencies and aliasing artifacts in the resultant image. However, if we don’t excite a large FOV, we don’t need to encode it.

Instead of using outer volume suppression pulses or inner volume technique where the excitation and refocusing pulse are orthogonal to each other, FOCUS uses a 2D RF excitation that is spatially selective in the slice select (SS) as well as phase encoding (PE) direction to excite a limited phase FOV extent (Figure 1). This specialized excitation pulse is incorporated in place of the conventional excitation in the ssEPI DWI sequence (Figure 2). The rFOV excitation also allows the user to exclude sources of artifacts that are outside the region of interest (for e.g., the lung cavity when scanning the thoracic spine) from the FOV. Such exclusions help to improve local field homogeneity conditions and minimize off-resonance artifacts, which would not be possible with some of the other ETL shortening techniques, such as parallel imaging and segmented EPI.

The 2D RF excitation is played out in conjunction with an oscillatory (fast) and a blipped (slow) gradient which traverse the excitation k-space in an echo-planar trajectory.
The specific design choices for FOCUS, which originated in close collaboration with Emine Saritas, PhD, and Prof. Dwight Nishimura, PhD, at the Electrical Engineering Department of Stanford University, also provide some unique benefits as briefly described below.

The choice of orienting the blipped/slow gradient along the SS direction also improves the performance and robustness of the technique. Firstly, it allows a very sharp profile in the phase FOV direction and minimizes aliasing. This design choice also maximally utilizes the slice selectivity of the refocusing pulse. Because of discrete sampling properties, periodic replicas or “side lobes” of the excitation profile appear along the SS direction. Due to lower bandwidth in the slice direction of the 2D excitation, fat and water profiles also experience considerable chemical shift displacement relative to each other along that direction. The slice-selective refocusing pulse does “double-duty” by choosing the on-resonance main lobe of water excitation, eliminating interference from the excitation side lobes as well as providing robust fat suppression. This is schematically shown in Figure 3. Aliasing from chemically shifted unsuppressed fat, a phenomenon commonly known as “fat ghosting” is a serious issue in conventional DWI. So the inherent fat suppression in FOCUS is a big bonus!
Let us consider an example scenario where conventional DWI has a pFOV factor of 1 and Y phase encodes, and the FOCUS scan prescription has a pFOV factor of 0.5 and 0.5Y phase encodes such that both acquisitions have the same spatial resolution. In this case FOCUS can provide images with reduced distortion at the same spatial resolution as conventional DWI, because its ETL is only half as long. Alternatively let us consider an example scenario where the FOCUS scan prescription has a pFOV factor of 0.5 but the same number of phase encodes (Y) as the conventional DWI. In this case it would acquire at twice the spatial resolution, with comparable distortion as conventional ssEPI DWI due to similar ETL. The reduced distortion has in fact made FOCUS an enabler for DW MR in regions of high susceptibility such as the thoracic spine, head and neck (Figure 4), the brachial plexus (Figure 5), and the organs in the abdomen and pelvis. Higher in-plane spatial resolution improves depiction of small anatomes (Figure 6) as well as reduces partial volume effects in heterogeneous tissue composition. Shreyas Vasanawala, MD, PhD, an eminent body and pediatric radiologist at Stanford University Medical Center and an early adopter of FOCUS, has been using FOCUS for imaging of prostate and rectal cancer, and in pediatric oncology and appendicitis applications. He reflected that his clinical prostate MR program never really took off until they started using FOCUS, and not for lack of interest. Now they have transitioned from two cases a year to an average of two cases a day. Dr. Vasanawala is using MR imaging primarily for image-guided targeted biopsies and since many of the prostate lesions are quite small, high resolution is essential for their delineation and localization. He further explains that he uses high resolution DW MR with

Figure 5. The brachial plexus is another region where conventional DWI images are often severely compromised by poor fat suppression and severe geometric distortion. Here we show an example of fiber tracking in the brachial plexus, processed from a high resolution FOCUS DTI scan on an Optima™ MR450w 1.5T system.

Figure 6. A case study of an 81 year-old who experienced sudden onset of dizziness and unsteady gait two days before the MR examination. There was no other known deficit or antecedent. FOCUS helped the radiologists at GIE-IRM Creil confirm the ischemic lesion of the cerebral trunk produced by thrombotic occlusion of the right vertebral artery.
FOCUS as a monitoring tool in patients with elevated Prostate Specific Antigen (PSA), which may help to avoid invasive therapy. Additionally, he has observed FOCUS is very useful in finding clinically relevant tumors. Dr. Vasanawala attributes the enabling of high resolution, reduced distortion, and robust fat suppression as the key reasons why he is able to obtain diagnostic quality DWI images in patients with bilateral hip replacement (Figure 7). His recommendation to his colleagues is if they are using DW MR in the pelvis they should definitely give FOCUS a try.

While the reduced FOV excitation helps shorten the total readout time in ssEPI, and in many cases achieves better B0 homogeneity within the FOV, one thing to keep in mind is that SNR is proportional to the excitation volume. Therefore, scan parameters such as number of signal averages/number of diffusion directions should be adjusted to boost the SNR. FOCUS is not limited by any special hardware requirements. It can be used on a standard clinical 1.5T or 3.0T MR system.

References
The 3D Heart
Cardinal Glennon creates life-size anatomically correct models of complex anatomy using MR imaging and 3D printing

Caring for some of the most ill children in Missouri and southern Illinois has been the mission of SSM Cardinal Glennon Children’s Medical Center (St. Louis, MO) for nearly 60 years. Ranked among the best children’s hospitals by *U.S. News & World Report* for 2014-2015, the hospital was also ranked 33rd for cardiology and heart surgery. More than 23,000 visits and procedures are performed each year at the Dorothy and Larry Dallas Heart Center at SSM Cardinal Glennon.
It’s the complex heart cases, such as congenital heart disease, where Cardinal Glennon has found that MR technology can play an important role in the children’s care. In many instances, the smallest patients have issues early on, and require intervention as well as continued follow up with medical imaging.

“Echocardiography is the most common imaging modality used in children with congenital heart disease. We minimize the use of CT scans in children due to radiation,” says Nadeem Parkar, MD, Chief of Cardiac and Thoracic Imaging at Saint Louis University and at Cardinal Glennon. “MR has zero radiation, and there are several aspects of cardiac imaging that can be reliably assessed by MR imaging, including right ventricular function, valvular stenosis and regurgitation, myocardial diseases such as myocarditis, and myocardial iron quantification.”

The pediatric cardiothoracic imaging program is keeping Dr. Parkar and Wilson King, MD, pediatric cardiologist, very busy. When Dr. Parkar first joined the hospital two years ago and started the cardiac imaging program, it was estimated that they would perform approximately 35 cardiac MR exams in the first year. By the end of the first year they had performed approximately 90 cardiac MR exams. Since December of 2012, these most precious patients have been imaged for pre-surgical planning at Cardinal Glennon on the wide bore Discovery™ MR750w 3.0T from GE Healthcare.

“These congenital heart disease cases are very complex,” Dr. Parkar explains. “We have two brilliant surgeons with over 50 years of combined experience. Even though they are exceptionally skilled, we believe that viewing the patient’s complex cardiac anatomy in advance would be beneficial. Imaging is two-dimensional, whereas the surgeons are always looking at 3D structures during the operation. So, we started to think about a way to provide them with 3D depth perception for their pre-surgical planning so they can anticipate what they will see in the OR.”
3D printing

In early 2014, Dr. Parkar and Dr. King were at the Society for Cardiovascular Magnetic Resonance (SCMR) meeting and heard about a new trend in 3D advanced visualization—3D printing—a process for making a physical object from a 3D computer model by laying down many successive thin layers of a material, such as plastic. Dr. Parkar thought it might be a useful, innovative approach to help the surgeon's pre-surgical planning and, together with Dr. King, explored the idea further. Unfortunately, with 3D printers costing between $100,000 to $200,000, the hospital didn't have the resources to acquire one.

However, Cardinal Glennon is affiliated with Saint Louis University and the University’s Parks College of Engineering, Aviation, and Technology has a 3D printer. Dr. Parkar and Dr. King met with Sridhar Condoor, PhD, Department Chair and Professor of Aerospace and Mechanical Engineering, to discuss their clinical needs.

“The Cardinal Glennon team explained a real need to help their surgeons visualize 3D anatomy from 2D images using 3D printing,” Dr. Condoor says. So, he took a MR imaging file, converted it to a 3D computer model, and created a solid heart to show them the amazing result. The 3D printer is a rapid prototyping machine that creates a 3D plastic model—layer by layer—based on the CAD file. “It looks like a plastic heart,” says Dr. Condoor.

Next, they took a CT angiography study and set out to create a hollow heart with the arteries and veins so the surgeons could see the internal representation of the intracardiac anatomy.

“Feedback was phenomenal,” says Dr. Parkar. The surgeons were impressed by the model and appreciated the ability to view a patient’s complex anatomy as a true 3D structure. It also became a great educational tool for residents in training and students, as Cardinal Glennon is a teaching hospital affiliated with the Saint Louis University School of Medicine and School of Nursing.

Sridhar Condoor, PhD,
is Chair of the Department of Aerospace and Mechanical Engineering and Program Director for Mechanical Engineering at Saint Louis University Parks College of Engineering, Aviation, and Technology.
Dr. King says the models also help him communicate the issue or defect with the surgeons and families. “Having this model available really helps the surgeon understand the defect and its relationship with the patient’s anatomy,” he explains. In addition to using the 3D model to plan the surgery, Dr. King has seen surgeons actually take a model into surgery. “It just gives them a better perspective.”

According to Dr. King, having the model bedside also helps nurses and family members understand the defect. “Better communication across all caregivers leads to better patient care,” he offers.

The value of MR

Within the last six months, the multidisciplinary team has created six 3D life-size models utilizing MR and CT. Cardiac MR studies primarily incorporate Black Blood double inversion recovery SSFSE, Cine FIESTA, phase contrast, and contrast angiography sequences that are available on the hospital’s Discovery MR750w; often, they’ll utilize perfusion- and delayed-enhancement sequences to look at the myocardium. Three-dimensional whole-heart Navigator allows acquisition of free breathing, high-resolution datasets.

“The Navigator sequence is cardiac and respiratory triggered, helping us to minimize motion artifact,” explains Dr. Parkar.

With the 3.0T magnet, Cardinal Glennon’s imaging staff can achieve higher signal-to-noise ratios (SNRs), which produce sharper images and help delineate contrast from the surrounding tissue, making it easier to build the life-sized 3D models. Recently, they’ve begun evaluating GE Healthcare’s 3D Heart sequence and find it promising for helping them visualize the patient’s complex cardiac anatomy.
We have these little babies...it's a big deal for them to undergo open heart surgery...our surgeons have a limited amount of time to complete the repair, and the model gives them a better perspective on what needs to be done.

Dr. Wilson King
Developing a Rapid MR Exam for Pediatric Acute Appendicitis

Appendicitis is the most common surgical emergency for pediatrics, with the highest incidence rate in children aged 10 to 19. Each year, approximately 270,000 appendectomies are performed in the United States.1

Diagnosing appendicitis typically involves an ultrasound or CT imaging study, or a combination of the two. Yet, ultrasound results are operator dependent with variable sensitivity and a high rate of nonvisualization due to the location of the appendix.2 While CT is a rapid and accurate test, there is exposure to ionizing radiation.

In San Diego, CA, Rady Children’s Hospital performs over 700 appendectomies each year, a rate that is second in volume in pediatric hospitals across the US, explains John H. Naheedy, MD, radiologist. Ultrasound is rarely utilized at the hospital for these type of cases; in addition to requiring highly experienced sonographers, which Rady Children’s has, it also requires physician time during the exam. Further, ultrasound is often equivocal.
in diagnosing appendicitis, Dr. Naheedy explains, which can require another imaging study.

Understanding the limitations of ultrasound and the desire to limit the use of ionizing radiation in pediatrics, radiologists at Sharp and Children's MRI Center (San Diego, CA), affiliated with Rady Children's Hospital, began to look into the use of MR as an alternate for imaging suspected cases of acute appendicitis in pediatrics. The need for an alternative was driven by the hospital's large number of appendectomies, and the facility's ER physicians further supported this effort.

However, there is a prevalent mindset in many ERs and hospitals that MR takes too long and costs too much, and therefore is not appropriate for emergency imaging cases, explains Keith Prince, CEO of Sharp and Children's MRI Center. "We wanted to change that paradigm by quickly providing MR abdominal results so the ER doctors could admit or release the patient in a timely manner."

Embracing this desire to utilize MR for imaging acute abdominal pain cases, Dr. Naheedy—along with Jeffrey Koning, MD, radiology resident, and Peter Kruk, MD, radiologist—initiated a clinical study on the performance of contrast-enhanced MR to help evaluate suspected acute appendicitis cases and other causes of abdominal pain in pediatrics. "We started to look at the published clinical data for accuracy and diagnostic performance of MR for appendicitis," Dr. Naheedy explains.

They also knew a key requirement for the adoption of an MR imaging test for emergency abdominal pain and suspected appendicitis would have to perform rapidly and reliably like a CT study, Dr. Koning says. Plus, MR offers excellent soft tissue contrast, which provides added information on other abdominal structures that a radiologist can use to help assess if the abdominal pain is the result of some other medical condition. "In our opinion, for an alternative diagnosis in the pelvic area, for example, MR is excellent," he adds.3

With pediatric patients, and in particular the very young ones, it may be difficult to know the true source of the pain, Dr. Naheedy explains. "Using MR, the soft tissue contrast is much better; while MR can do just as well as CT in many areas of the body, we find it can be superior in cases of pelvic pathology," he says.

For example, in cases of inflammation of the bowel, a condition that can be medically managed, or in young girls suffering from dysmenorrhea, or

Figure 1. A 14 year-old with perforated appendix. Axial T2 frFSE image demonstrates a hypointense focus representing an appendicolith (white arrow), with surrounding infiltration and stranding of the periappendiceal fat (A). Axial post-contrast LAVA Flex image at a lower level in the same patient demonstrates a markedly dilated appendix and surrounding hyperenhancement in the periappendiceal fat (B). Coronal post-contrast LAVA Flex image demonstrates similar findings, with abnormal enhancement of the appendiceal wall (C, white arrow).
Frederick, along with the radiologists at Sharp and Children’s MRI, then evaluated every possible abdominal sequence looking for ones that provided duplicate information. For example, duplicate chemical suppression or FatSat sequences could be eliminated, Frederick says.

The result was a 20 minute abdominal MR exam—50% shorter than their previous exam—consisting of coronal FIESTA with FatSat; coronal T2w single-shot; axial DWI; axial FIESTA with FatSat (thin cut); axial T2 single-shot; and a post-contrast LAVA Flex in two planes—axial and coronal.

To shorten exam time, it was also important to define the region of interest so the scan would only cover the body area pertaining to the clinical question. “The upper part of the abdomen is not needed,” explains Frederick. “We scan from the top of the abdomen to the level of the girl’s ovaries, which can be severe during a young girl’s first ovulation—menstrual pain—which can be severe during a young girl’s first ovulation—Dr. Naheedy says that MR is ideal.

**Evaluating the protocols**

The first step in developing a rapid MR exam for imaging suspected cases of acute appendicitis was for the hospital to evaluate existing MR protocols and determine which ones were most important to use regarding abdominal pain. “In my experience, test specificity does not change by shortening the sequences,” Dr. Naheedy explains. “If we see something and it’s not the appendix, we can add more sequences and that could increase sensitivity.” There were several instances, using MR, when the team found a liver or kidney mass that was causing the abdominal pain.

Sharp and Children’s MRI Center’s Michael Frederick, RT(R) (MRI), Technical Services Supervisor, and Jerry Dwek, MD, Chief of Pediatric MR, were also instrumental in the workflow and protocol development. Dr. Dwek set the bar high, specifying that speed and quality of information would be the critical factors.

Having an MR exam completed in a timely manner was important to answer the urgent medical question adds Dr. Kruk, and timeliness would depend on the number of sequences utilized. “We needed to get them through quickly for fast results, but we also had to address report turn-around times.”

Dr. Naheedy and Dr. Kruk, under the direction of Russell Low, MD, Medical Director, determined the most useful sequences were post-contrast LAVA Flex and eDWI (see sidebar). “We find that with contrast, the appendix wall enhances, helping make it more evident there is an inflammation,” says Dr. Kruk. “Without contrast, it can be hard to find the appendix. With MR’s excellent contrast resolution, we can see the post-contrast enhancement that, in some cases, enables us to detect inflammation in the very early stages of appendicitis.”

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**Peter Kruk, MD,**

is a radiologist with Sharp and Children’s MRI Center, and Chief of Pediatric Radiology and Medical Director of Radiology at Rady Children’s Hospital.

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Figure 2. A 13 year-old with appendicitis. Coronal T2 frFSE image demonstrates a hypointense focus representing an appendicolith (white arrow), with a dilated appendix distal the appendicolith (A). Coronal T2 FIESTA image showing similar findings, with hyperintense fluid filling the dilated appendix (B).
the right kidney to the bottom of the bladder." For the axial FIESTA with FatSat, Frederick notes that it was important to have a thin cut axial throughout the region of interest.

The team also examined which MR tools could help save even more time. Frederick discovered PROPELLER 3.0 was an invaluable sequence in cases of uncooperative patients. However, with the entire exam lasting only 20 minutes, he explains more children are able to stay still and cooperate.

A focus on workflow

To accommodate the urgent MR imaging cases, the radiology team evaluated patient workflow and throughput. "Prior to initiating the study, workflow in the MR department was first in, first out. Getting an ER patient on the next available scanner was not the typical workflow," Frederick says. "We had to change that workflow." This took the cooperation and coordination of the ER and the radiology departments – from clerks to physicians, as well as nursing.

As soon as the order came in from the ER, an MR staff member immediately retrieved and screened the patient. Typically, this would be handled by the ER nurse; however, the team realized that the ER nurses handle multiple patients and may not be able to perform this duty at the time of the order. So, to save time and speed up the process it was decided that the MR department would handle this responsibility.

Nurses played an important role in ensuring a smooth workflow. Since the team wanted to utilize contrast in the MR study, they worked with the ER nurses to ensure that all pediatric patients with suspected appendicitis received a working IV in the ER. When the patient arrived at the scanner, nurses were available to help hook up the IV to the contrast injector and stay with the child to provide reassurance.

"We found that having nurses in the room helped with patient compliance... the patients were more cooperative," Frederick says. "It's the little things that helped make this run more smoothly," he adds. "We also had a strong effort from our MR clerk to turn around the MR scanner room quickly for these ER patients."

Figure 3. Teenage female with right lower quadrant pain. Axial 1.5T FRFSE T2w image of the pelvis demonstrates a fluid-fluid level in the right ovary consistent with a hemorrhagic ovarian cyst (A, white arrow). Axial 1.5T FIESTA image at the same level in the pelvis shows significant surrounding free fluid in the pelvis (B).
The findings

In March of 2014, Pediatric Radiology published the study results co-authored by Drs. Koning, Naheedy and Kruk demonstrating their ability to accurately diagnose acute appendicitis by using their MR protocol. A second paper, focused on comparing the accuracy of first-line MR between children with different durations of abdominal pain, was published in the August, 2014 edition of Abdominal Imaging. The studies were based on the MR imaging performed on Sharp & Children’s MRI Center’s 1.5T GE scanners: a Discovery™ MR450 and a SIGNA™ HDxt and SIGNA™ LX with HD23.0 upgrades.

In the first paper, the authors performed a retrospective review of 364 patients assessed between November of 2012 and September of 2013. “Based on the data, we concluded that contrast-enhanced MR can help in our diagnosis of acute appendicitis while also assisting us with identifying alternative causes for the abdominal pain, such as colitis, enteritis or terminal ileitis, adnexal cysts, and mesenteric adenitis,” says Dr. Koning, lead investigator of the study. “We reported a sensitivity of 96.2%, a specificity of 95.7%, a positive predictive value of 92.7%, and a negative predictive value of 97.8%.”

As important is the efficiency of the study. “We’ve shown that we can complete the scan and provide interpretation within an average of less than two hours after the time the study is ordered,” explains Dr. Koning.

“This study is integral in showing that radiologists are listening to parents and other clinicians who are concerned about ionizing radiation from CT studies,” Dr. Koning adds. “We are actively investigating viable alternatives to provide excellent medical care and an accurate diagnosis of a child in acute abdominal pain.”

Dr. Naheedy agrees, adding, “This study indicates that for this common pediatric problem, we can diagnose without radiation and provide the information ER physicians need for patient treatment. It is welcomed by the patients’ parents.”
In the Abdominal Imaging article, they compared the diagnostic performance of MR in two groups of children: those with early symptoms and those with prolonged symptoms. Dr. Koning explains, “We concluded that MR is just as accurate in children with early symptoms of appendicitis as it is in children with later symptoms, suggesting it may be appropriate to use MR as a first-line test for clinically suspected appendicitis.” However, they do highlight the need for additional prospective studies. Dr. Koning also believes it would be of interest for future studies to evaluate the accuracy of non-contrast MR with contrast-enhanced MR.

In 2014, Sharp and Children’s MRI center is on pace to perform 400 pediatric ER MR exams, according to Prince. Not all of these cases are acute appendicitis. “We’ve made ordering MR studies by the ER docs convenient by removing barriers and providing quick turn-around times with our reports,” he says.

One such barrier was the perception that MR takes longer than CT. “Because we adjusted our workflow to accommodate faster turn-around times, our new MR pediatric abdomen protocol can actually compete with a CT abdomen study,” states Prince.

While there is no cookie-cutter approach, Prince encourages other pediatric hospitals to explore changes in protocols and patient management that provide positive benefits. It isn’t easy, but it can be done by engaging the clinical staff that has a stake in the process. Prince adds, “Our vision is to use the most appropriate imaging tools we have so our pediatric patients can have potentially better outcomes.”

Russell N. Low, MD, is Medical Director at Sharp and Children’s MRI Center in San Diego and since 1991 has practiced with San Diego Imaging Medical Group. He received his medical degree from the University of California, San Diego, with honors and participated in the NIH Research Training Program. Dr. Low interned at St. Mary’s Hospital and Medical Center (San Francisco) and completed his residency in diagnostic radiology at the University of California, San Francisco and his fellowship in MR/CT/Ultrasound at Stanford University Medical Center (Palo Alto, CA). He has authored over 60 articles and five book chapters, and is a frequent speaker at symposiums and conferences, including RSNA and SMRM.

Peter Kruk, MD, a radiologist with Sharp and Children’s MRI, is also Chief of Pediatric Radiology and Medical Director of Radiology at Rady Children’s Hospital. He earned his medical degree from Indiana University School of Medicine and completed his internship at Illinois Masonic Medical Center in Chicago. Dr. Kruk also completed his radiology residency at Emory University, pediatric radiology fellowship at Harvard University Boston Children’s Hospital, and mini musculoskeletal radiology fellowship at UCSF.

John H. Naheedy, MD, a radiologist with Sharp and Children’s MRI, received his undergraduate degree at the University of Michigan. He completed his medical degree at Ohio State University, College of Medicine. He completed an internship for Internal Medicine at Santa Barbara Cottage Hospital and his diagnostic radiology residency at the University of California, San Diego (UCSD). Following his residency at UCSD, he received his fellowship training in Pediatric Radiology at Harvard University Boston Children’s Hospital.

Jeffrey L. Koning, MD, radiologist, is currently completing his diagnostic radiology residency at UCSF. He earned his medical degree from Loma Linda University School of Medicine, where he was a member of the Alpha Omega Alpha Honor Medical Society. As an undergraduate, Dr. Koning graduated at the top of his class in the School of Business and Management at La Sierra University. In 2016, he will be a clinical pediatric radiology fellow at Boston Children’s Hospital/ Harvard Medical School.

Keith Prince began his MRI career at Sharp and Children’s MRI Center in 1986 as an Orderly. He continued his training as an MRI Technologist on-site and received specialized MRI training at the GE Healthcare Training Center in Waukesha and Brookfield, Wisconsin. After 17 years as Chief Tech at Sharp and Children’s MRI Center, he was an MRI Applications Specialist for GE and established an MRI school to train MRI Technologists for national certification. After working for an international 3D medical imaging software company and as Executive Director for San Diego Imaging Chula Vista, he returned to Sharp and Children’s MRI Center as their CEO in 2010.

Michael Frederick, RT(R) MRI, is the Technical Services Supervisor at Sharp and Children’s MRI Center.

Sharp and Children’s MRI Center LLC was founded in 1986 by Sharp Healthcare, Rady Children’s Hospital, and San Diego Imaging Medical Group to provide comprehensive diagnostic imaging for children and adults.

References
In Practice

Early in the development of LAVA Flex, GE shared the beta release with Dr. Low and Sharp and Children's MRI Center. “We would evaluate the release and provide our feedback. GE would then adjust the sequence and we would find out whether those changes worked. They always respected our input,” Dr. Low says. While at the time he didn’t know what the result would be, he was very pleased to see the collaborative efforts appear in the commercial version of LAVA Flex.

“LAVA Flex is just a powerful tool.” Now in one breath-hold, we can create in-phase and out-of-phase pure fat and pure water images and use them as our post-contrast fat suppressed images,” Dr. Low explains. “Today it is very fast and efficient with virtually no inhomogeneity and provides up to 25% improvement in SNR.”

Cases of inferior fat suppression may mask enhancement and therefore contribute to a misdiagnosis, Dr. Low says. With the homogeneity of LAVA Flex, radiologists at Sharp and Children’s can potentially detect the inflammatory enhancement. He considers LAVA Flex an industry standard today.

Additionally, with an MR study utilizing both LAVA Flex and eDWI, the radiologists can look at other areas in the abdomen that may be causing the abdominal pain, including the kidneys, gallbladder, or biliary tree. “With MR, we can easily look at those structures so we can determine related disease and be more confident with our diagnosis. Together, LAVA Flex and eDWI provide us with a tremendous ability to see disease in both pediatrics and adults,” Dr. Low concludes.

For over a decade, GE Healthcare has collaborated with the talented radiologists at Sharp and Children’s MRI Center under the direction of Russell Low, MD, Medical Director. “Our collaboration is a wonderful example of how science and engineering can ultimately benefit patients,” he says. Sharp and Children’s was involved in the early development of the two critical sequences used in the MR protocol for pediatric abdominal imaging—GE’s LAVA Flex and eDWI. Dr. Low explains that GE was the first MR company to bring Dixon imaging to the forefront with LAVA Flex.

LAVA Flex is a 3D, FSPGR imaging technique that generates water-only, fat-only, in-phase and out-of-phase echoes in a single acquisition that is typically completed in one short breath-hold. This technique provides excellent homogeneous fat suppression over the entire field-of-view, including areas that are difficult to image using conventional fat suppression due to magnetic susceptibility effect.

abnormal enhancement visualized on LAVA Flex, they are the key markers for appendicitis that radiologists look for.

The eDWI technique is designed to provide high signal-to-noise-ratio (SNR) diffusion images with a short acquisition time. Its multi-b feature can provide measurement of apparent diffusion coefficient (ADC) map with a reduced effect of perfusion. In addition, this “3 in 1” technique applies diffusion weighting to all three gradients simultaneously, helping improve sensitivity. Plus, the built-in tetrahedral feature applies four different diffusion-weighting combinations of x, y, and z gradients simultaneously to acquire isotropic, diffusion-weighted images with high SNR and shorter TE.

eDWI is the other crucial body imaging sequence in the MR protocol used for pediatrics with suspected acute appendicitis. “eDWI will show us corresponding areas of restricted diffusion,” Dr. Low says. Along with the
Improving the MR Experience for Pediatric Patients

Centre Oscar Lambret (COL) is a dedicated regional cancer center in Lille, France—the country’s fourth largest city with 1.2 million inhabitants. Ninety percent of the practice’s patients arrive with diagnosed cancer, so follow up begins with an MR scan to help clinicians select the best treatment plan. Ten percent are occasional patients who have a mass or nodule found by a CT or ultrasound, and they are sent to COL for an MR scan and lesion characterization.

In 2010, the facility was scanning 16 MR patients daily but, thanks to workflow and productivity improvements with their Discovery™ MR750 3.0T from GE Healthcare, COL has increased that number to around 20. This is without additional patients who could be added in emergency cases.

“There’s a strong need for dedicated pediatric oncology centers because the cancer and therapeutic strategies can be very different from those of adult oncology. Plus, experienced, skilled technologists are needed to properly scan young children,” says Nathalie Rocourt, MD, radiologist at COL. Additionally, she explains that liver tumors are different in pediatrics than in adults. For example, hepatocarcinoma is found mostly on healthy livers in pediatrics, which differs from adult hepatocarcinoma that often occurs on cirrhotic livers.

“Our answer was simply that we ran the LAVA pre-contrast and the whole LAVA dynamic series with the Navigator. In the end, this free-breathing exam is just a lot less exhausting for the pediatric patients and it clearly improves their MR experience.”

Arnaud Fournier
Dr. Rocourt points out that abdominal MR imaging plays an important role in helping her site plan the pediatric therapeutic strategy, such as a partial hepatectomy. In these cases, MR provides the information oncologists need to assess how many liver segments are affected by the tumor. Liver grafting is also a strategy that requires assessment of the lymph node local extension or peritoneal carcinosis existence. MR sequences such as T2, diffusion, and T1 with gadolinium are helpful in planning these treatments.

“If a pediatric patient has local extension of the tumor, where it has spread to the lymph nodes, then it rules out the patient for a liver graft. MR is a useful tool for helping determine if the lesion has infiltrated the lymph nodes. With MR, we can also determine how many liver segments are affected by the tumor and any involvement with intrahepatic vessels and the portal vein in order to assess hepatectomy feasibility,” comments Dr. Rocourt.

In an initial examination, MR helps provide information to characterize the lesion so the oncologist can determine the therapeutic strategy, including determining if the cancer has spread to the portal vein, for instance. In addition to diagnostic uses, MR has the potential to be used for treatment monitoring. Some chemotherapy-induced Focal Nodular Hyperplasia (FNH) might occur. According to Dr. Rocourt, MR is the only imaging modality that provides the information clinicians need to differentiate FNH from a local recurrence or a secondary lesion.

“The preferred modality

Dr. Rocourt adds, “MR is our preferred modality because it is a non-irradiating imaging technique and these children will be followed up for a very long time due to their disease.”

It is well accepted that MR has a much better soft tissue contrast than CT. “MR is clearly used more for tumor characterization, resulting in access to functional imaging of the tumor through diffusion, perfusion, or spectroscopy. In some cases, only MR can give us more information about what kind of lesion it is,” states Arnaud Fournier, MR technologist at COL.

Dr. Rocourt adds that she prefers use of this imaging tool in the head and neck. “For us, neuroimaging has already shifted most of the first-look examinations from CT to MR. We believe MR clearly has great potential in replacing CT in a lot of pediatric imaging situations.”

Fournier continues, “Because of this, MR imaging is crucial to our oncology department. Also, it’s starting to pave the way for new imaging biomarkers such as pharmacokinetic modeling, especially Ktrans. MR is also very important because we have almost no delay in programming a patient scan just before treatment. Plus, we can keep patients at our facility during the entire medical pathway, which is more comfortable for them.”

**Arnaud Fournier**
has been an MR technologist at Centre Oscar Lambret (COL) in Lille, France since 2009.

**Nathalie Rocourt, MD,**
is a radiologist at COL with 16 years of experience in pediatric and oncology imaging.
because pediatric brain tumors are often located in the posterior fossa where Cube performs very well with its flow correction capability and allows assessment of post-therapeutic changes.

**Upgrade increases productivity**

COL recently had GE Healthcare’s DV24.0 Continuum™ Pak installed on its Discovery MR750 3.0T. The upgrade is GE’s response to clinicians’ ever-changing diagnostic needs with a robust collection of solutions to improve workflow and supercharge applications. Paquier and Fournier agree that the upgrade has increased productivity. “Prescan time reduction has helped us reduce the total scan time, and it’s one of the main reasons why we have a higher patient throughput today. We definitely feel that workflow has improved with DV24.0,” says Paquier.

Before the upgrade, Fournier says that doing T1w images pre- and post-contrast on pediatric patients under six years old had been a great challenge. “We used to let the patient breathe, scan the sequence, and try to manage the artifact through post-pre subtraction images. T2 PROPELLER is great because T2 contrast is essential for tumor characterization, but our patients are often in a great deal of pain and there is a strong need for motion and respiratory artifact correction.”

COL uses several key applications for pediatric tumor detection and characterization—depending on the study. “In body imaging, we perform really high image quality in Diffusion...”

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**Benefits of 3.0T**

Some of COL’s patients arrive with a CD of their last MR scan so the staff sees many images that come from other MR systems. Most are taken at 1.5T, since 3.0T only encompasses 10% of the total MR system installed base in France.

“The images from other MR scanners lack spatial resolution and T1 contrast especially after contrast administration,” says Marie-Noëlle Paquier, MR Technologist at COL. “We feel that volumetric and perfusion T1w acquisitions are much better on our 3.0T system. Since oncology requires a 3D approach of the tumor, we are confident saying that oncology really benefits from the 3.0T technology.

We are also using the high spatial resolution of 3.0T MR with several functional biomarkers of MR to assess treatment response.”

In addition to the high spatial resolution, Dr. Rocourt adds that 3.0T is clearly better for cerebrospinal examinations and soft tissue investigations with its excellent tissue contrast. “Another great thing about 3.0T is that the scanning time is generally shorter, which lets the technologists run more MR sequences without having to choose because of time limitations. They can scan diffusion, T2 in several planes, FLAIR, T2*, and T1 pre- and post-contrast in less than 20 minutes. They really like Cube for pediatric neuroimaging...”

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**Figure 1. Free-breathing Axial LAVA dynamic: mask phase (A) and three consecutive contrast-enhanced phases over the arterial and venous phases (B, phase 1; C, phase 2; D, phase 3).**
Weighted imaging (DWI) with multi b-values and automated ADC in-line processing. Additionally, we are doing more DCE-MR, and 3D LAVA post-contrast is often required by our radiologists because it gives cubic millimeter isotropic volumes in which they can investigate the tumor in all possible planes. Neuro cases require more T1w images such as Cube T1 FSE or 3D FSPGR with contrast enhancement, “ offers Fournier.

According to Dr. Rocourt, in her facility, DWI is a necessary sequence that aids in pediatric tumor visualization of primary or secondary lesions and local lymph node extension. “We use T2* for blood detection, especially in adrenal gland tumors where there's a need to identify hematomas and bleedings, and T2w in two planes most of the time. T1 pre- and post-contrast are also in strong demand in pediatric imaging.”

Improved MR experience

COL appreciates the robustness and efficiency of LAVA combined with Navigator for contrast-enhanced abdominal imaging in the pediatric population. As part of the DV24.0 Continuum Pak, Body Navigator is designed to allow for free breathing, motion-controlled acquisitions. DWI, MRCP, T1, and T2 high-resolution images are scanned without a breathhold and now COL’s routine liver imaging is performed in less than 15 minutes. “When it comes to pediatric MR, LAVA Navigator has improved the reproducibility in image quality, and therefore our diagnostic capabilities. Previously, T1 post-contrast had been almost impossible to perform with these qualities,” says Dr. Rocourt.

Paquier adds that LAVA Navigator can be easily handled by any trained technologist. Plus, they find the tracker positioning is easy and there are diagrams in the protocol notes to help place it. “The Navigator is also very flexible, as we can adjust the threshold and the acceptance window which allows us to adapt to very difficult patients who often change their breathing patterns.”

**Insight...**

The brand new DV25.0 Continuum™ Pak upgrade further reduces overall scan time and breath-hold time in abdominal imaging. See page 11 for more information.

Figure 2. Respiratory triggered Axial T2 FatSat PROPELLER (A), showing excellent contrast-to-noise ratio and no respiratory/motion artifacts. Free-breathing Axial LAVA high-resolution 2.6 mm native slice thickness after contrast injection (B). Yellow arrows depict a mildly enhancing liver tissue area that was previously seen with CT (C).
It’s easier to get the MR system to adapt to the patient than the other way around, especially on young patients. Navigator embodies this way of thinking. Sedation shouldn’t be an easy way out—it should be a last-case scenario. 

“...Gamma Fournier

Fournier continues, “One very time-saving feature is the ability to copy the tracker between series. The Navigator also accommodates a wide range of contrast such as DWI, T1, T2, and 3D T1. On very young pediatric patients who are prepped outside of the MR scanning room, it’s good to have the Navigator to perform standard contrast such as T2 and DWI. But the real improvement is the compatibility with T1w LAVA and LAVA Flex, because there’s no solution other than the breath-hold technique. We have found it can save the entire LAVA dynamic series from having to be repeated on pediatric patients and those who are completely unable to hold their breath.”

With pediatric patients, COL also uses GE’s PROPELLER technique for T2w contrast. However, since the respiratory bellows are difficult on patients younger than five years old, it’s more convenient to prepare them outside the scanning room—in which case they use the Navigator for T2w contrast and DWI. With the use of Navigator techniques, COL hopes the number of sedations for young pediatric patients will progressively be reduced. “It’s easier to get the MR system to adapt to the patient than the other way around, especially on young patients. Navigator embodies this way of thinking. Sedation shouldn’t be an easy way out—it should be a last-case scenario,” states Fournier.
Arnaud Fournier has been an MR technologist at Centre Oscar Lambret (COL) in Lille, France since 2009. He scans patients on GE’s Discovery MR750 3.0T; as a result, he authored posters on kidney MR at 3.0T for the French Society of Radiology and how to perform an MRI without sedation on a child under five years old for the French Congress of Radiology.

Marie-Noëlle Paquier, an MR technologist at COL since 2001, works with MR, breast imaging, and general radiology. She holds a Medical Imaging Technologist Degree.

Nathalie Rocourt, MD, is a radiologist at COL with 16 years of experience in pediatric and oncology imaging. Dr. Rocourt is a member of the French Society of Radiology and French Society of Children Cancers, and she has been published in many scientific papers.

Centre Oscar Lambret (COL) in Lille—the fourth largest city in France with 1.2 million inhabitants—is a dedicated cancer center, highly specialized in oncology. Through its threefold mission of patient care, teaching, and research, the facility has developed an integrated patient care solution accounting for all aspects of cancer. COL welcomes more than 16,000 patients annually.

The Clinical Potential for LAVA Post-Contrast With Navigator

According to Dr. Rocourt, neuroblastoma is the most common solid tumor for pediatrics up to five years old, and it can be located in many different places including the abdominal cavity. Neuroblastoma surgeries can be very complicated and the surgeon needs to visualize the following aspects to determine the type of surgery to perform with as little risk as possible:

- 3D visualization of the enhanced tumor to allow accurate delineation;
- 3D visualization of the vessels, including tumor location in relationship to the vessels; and
- Local assessment of lymph nodes.

In reference to the images in this article, currently, this information is provided by contrast-enhanced CT at the portal phase; however, contrast-enhanced LAVA with Navigator at the portal phase appears to have similar potential. 3D MIP allows visualization of the vessels and LAVA has a high spatial resolution to potentially perform accurate tumor delineation.

Dr. Nathalie Rocourt concludes by stating, “In pediatric oncology, MR is crucial for us to characterize lesions and elaborate therapeutic strategies, whether it is surgery or radiation therapy. DWI, T2, and T1 post-contrast are three key sequences that we use to investigate tumor behavior and local extension as thoroughly as possible. Before DV24.0, however, the T1 image quality in post-contrast studies was too poor to be reliable, due to the fact that patients were unable to hold their breath. LAVA Navigator has opened a very important chapter of pediatric liver imaging, allowing us to characterize or detect small liver lesions, providing information on how vessels could be affected by the tumor and assessing local extension. Based on our experience in abdominal pediatric imaging, we hope to continue elevating the use of MR for cancer treatment follow up, especially on radiosensitive patients.”

The editors thank GE Healthcare’s Bastien Perez, MR Zone Clinical Leader, Oncology & MSK Europe, for his extensive contributions to this story.
In Practice

Intraoperative MRI (iMRI) is helping to change the way that surgeons can treat neurological disorders and disease. Over the past several years, clinicians at the University of Wisconsin (UW) Hospitals and Clinics and the University of California, San Diego (UCSD) Health Sciences have been using iMRI technology to help patients who they otherwise might not have been able to treat.

“I have had patients whose lives are completely transformed by these surgeries,” explains Clark C. Chen, MD, PhD, Chief of Stereotactic and Radiosurgery, Vice Chairman of Neurosurgery, and Associate Professor of Surgery, UC San Diego School of Medicine. “Prior to the availability of this type of technology, we had patients with brain cancer with no surgical option. In some cases, we can provide a treatment that impacts the quality of their life.”

Dr. Chen has been instrumental in building the iMRI neurosurgery program at UC San Diego, whereby real-time MR guidance is used during minimally invasive biopsy and treatment. The impetus for acquiring the technology was driven by patient need. “For many patients, performing an open surgical resection may bear more harm than good. With minimally invasive neurosurgery, we can help many of these patients.”

The GE Healthcare Optima™ MR450w 1.5T wide bore MR scanner is a shared resource with the radiology department at UC San Diego. The dedicated team is comprised of a neuroradiologist, anesthesiologist, nurses, MR technologist and Dr. Chen.

In 2016 the new Jacobs Medical Center at UC San Diego will open, featuring the A. Vassiliadis Family Hospital for Advanced Surgery. This facility will have 10,650 square-foot operating rooms.

A Tale of Two Hospitals
Taking real-time, MR-guided surgery to the forefront

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with integrated advanced diagnostic and imaging technologies.

“I am grateful for a highly collaborative research team and the visionary UCSD leadership who supported the innovative use of diagnostic MR to address critical needs for our brain tumor patients,” Dr. Chen adds.

At the University of Wisconsin Hospital in Madison and Baptist Memorial Hospital Semmes-Murphey Clinic (Memphis, TN), Karl A. Sillay, MD, has spearheaded the development of MR-guided neurosurgical techniques for deep brain stimulation (DBS) procedures and MR-guided surgery teaching. “In certain cases, intraoperative MRI expands access for patients who would otherwise decline surgeries,” Dr. Sillay says.

DBS has traditionally been performed with the patient awake and only lightly sedated, so the neurosurgeon can monitor electrical activity in the brain and ensure the wires are correctly placed. However, Dr. Sillay explains that many patients who could benefit from this procedure refuse it simply because they don’t want to be awake during it. “The ability for the patient to be asleep during these procedures means there are more people we can help.”

In an effort to further expand patient access to MR-guided DBS and other procedures, Dr. Sillay joined Semmes-Murphey in the summer of 2013. He retained his position at UW Madison and continues to perform neurosurgeries and MR-guided procedures in Madison on the Optima MR450w 1.5T wide bore scanner. (For more on UW Hospital–Madison’s iMRI see tiny.cc/spa141.

**Patient impact**

Real-time MR visualization and guidance using the GE scanner and ClearPoint® Neurosurgical Platform during neurosurgical biopsies is changing the way Dr. Chen operates and also the pathology that he can obtain. Traditional stereotactic biopsies on tumors located deep in the brain are performed in a “blinded” manner.

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Figure 1. MR shows 1 mm thin peri-ventricular enhancing lesion (A). The patient underwent a conventional biopsy without definitive diagnosis. Post-operative MRI revealed that the site of the biopsy was not located in the lesion. The patient was referred for an MRI-guided biopsy. Intraoperative MRI images demonstrate the biopsy site in real time (B, C). Pathologic analysis of the specimen secured from the MRI-guided biopsy (D) revealed primary CNS lymphoma. Note the small incision site with MR-guidance (E).
The surgeon has no true sense of where the biopsy needle is located in real time, Dr. Chen explains. “We triangulate the position of the needle based on a number of physical parameters.”

However, with minimally invasive technologies and MR guidance, Dr. Chen can now visualize the tumor and the biopsy needle in real-time during the procedure. “The ability to visualize is transformative, as this information allows the neurosurgeon to react in real-time,” he adds. In addition to knowing the location of where to biopsy the lesion, he can also see if there is any bleeding or other complications at the time of the procedure.

Perhaps even more important is the ability to take multiple biopsies from different targets in the tumor, while helping ensure pathology collection isn’t causing harm to the patient. “In today’s world, where genomics will increasingly dictate cancer treatment, it is important to capture sufficient pathology specimens for sophisticated genetic analysis,” Dr. Chen says. “In order to sequence tumors and determine what mutations the tumor harbors, we need ample clinical specimens. Insufficient clinical specimen will exclude some patients from clinical trials. So, today’s neurosurgical biopsy is not just about getting an accurate biopsy, but obtaining enough specimen for genomic and epigenomic analysis and clinical trial enrollment.”

Dr. Chen is also performing DBS procedures and novel treatments utilizing intraoperative MR and expanding the capabilities of traditional MRI suites to incorporate intrabore real-time procedures. One clinical trial that he is currently participating in is the delivery of viruses engineered to destroy brain tumors. He also uses the iMRI for tumor ablation, where a special probe “burns” the cancerous cells to kill them. In Dr.
Dr. Chen sees opportunity to accomplish this in the future. He notes that continued integration of the planning software with the MR scanner, automated or remote access to system controls via Bluetooth technology, and continued increases in computational power may all impact surgical time in the future.

"Faster sequences and an integrated workflow can increase the efficiency of MR scanning time, which ultimately can help shorten the procedure time," Dr. Chen says. "We need to continue to push the frontiers of technological development to help our brain tumor patients. For those who are satisfied with the care of today, there is no tomorrow."

Chen’s experience, “These procedures are possible only with real-time visualization provided by the MRI.”

With the wide bore MR, there is more room for other devices, such as catheters or head frames. Dr. Chen uses tractography for surgical planning, while a specialized sequence for MR thermometry that UCSD developed is utilized for laser ablations and electrode placements. When imaging patients during biopsies, a T1 post-contrast is most often utilized during the procedure to help ensure the tumor has been adequately sampled.

The newer, minimally invasive procedures can have a significant impact on the patient’s recovery. “The major difference is that the amount of skin and tissue manipulated for a minimally invasive surgery, compared to a craniotomy, is significantly less,” says Dr. Chen. “There is less trauma to the patient, so the recovery time is shorter and they typically can resume their normal activities earlier. We have many patients in the community singing the praises for the treatment they’ve received.”

Recently, in the case of a patient undergoing minimally invasive surgery for a deep brain lesion, Dr. Chen accessed the area of interest through a 3 mm incision. The biopsy was performed successfully with definitive tissue diagnosis and sufficient specimen for genomic analysis. More importantly for the patient, Dr. Chen closed the access point with Dermabond and the patient reported he felt like he never even had neurosurgery. “This kind of minimally invasive neurosurgery would not be possible without the aid of real-time MRI guidance,” he says.

While today’s advanced technologies, such as wide bore MR and MR-guided surgical planning software, don’t necessarily decrease neuro surgical time, Dr. Chen sees opportunity to accomplish this in the future. He notes that continued integration of the planning software with the MR scanner, automated or remote access to system controls via Bluetooth technology, and continued increases in computational power may all impact surgical time in the future.

"Faster sequences and an integrated workflow can increase the efficiency of MR scanning time, which ultimately can help shorten the procedure time,” Dr. Chen says. “We need to continue to push the frontiers of technological development to help our brain tumor patients. For those who are satisfied with the care of today, there is no tomorrow.”
A clinical study

In addition to being at the forefront of performing DBS procedures on an anesthetized patient in an iMRI suite, Dr. Sillay has also been involved in several studies investigating the use of MR guided surgery techniques and targeted drug delivery. He’s excited at the prospect of helping provide greater access to iMRI procedures for patients afflicted with various neurological disorders and diseases.

“For neurological applications and neurosurgery procedures, because we are able to visualize the target and the structure that we pass through in order to do the implantation, we are no longer limited by the visualization but rather by the technology,” Dr. Sillay says. What’s still lacking, he says, are new devices designed for use in minimally invasive neuro laser ablations or drug infusions. For example, many brain ports are still based on large surgical openings. While this is changing, with new device technology being brought to market, he sees a need for continued product development.

In October 2014, Clinical Neurology and Neurosurgery published an article by Dr. Sillay and several of his colleagues at UW Madison on their initial experience using MR-guidance to perform DBS in 10 patients who were asleep for the surgery. Patients were prepped for both anesthetized surgery and MR imaging, following guidelines from the American Society of Anesthesiology and performing standard MR safety checks. A 6-channel, 2-paddle flexible surface coil from GE Healthcare was placed between the patient’s head and the head fixation device. Scout checks confirmed imaging location in the scanner and functionality of the coils. Further MR imaging with MR-visible skin fiducials was then performed for planning the electrode placement using ClearPoint navigation software, with careful attention to avoiding critical cranial vasculature.

After completing the trajectory planning, alignment was confirmed with additional MR imaging. The dura was opened, ceramic stylets were placed, and imaging confirmed proper placement by enabling measurement of the trajectory to the planned target region. Once confirmed, the ceramic stylets were replaced with the DBS implant and imaging verified correct positioning and checked for potential complications.

In addition to concluding that MR-guided stereotaxy is a “reasonable alternative to MER-guided surgery” for DBS procedures, the authors reported that surgical time decreased with experience. The average surgical time for the first three cases was eight hours, while the last three cases were under five hours.

“The decrease in surgical time is due to increased efficiency gains and procedural learning among the staff,” Dr. Sillay explains. He also

There is less trauma to the patient, so the recovery time is shorter and they typically can resume their normal activities earlier. We have many patients in the community singing the praises for the treatment they’ve received.”

Dr. Clark C. Chen
Intraoperative MR

GE Healthcare has a strong legacy in the evolution of intraoperative MRI (iMRI), beginning with installing the first iMRI in 1994. Since then, GE has proudly contributed a series of "firsts" in surgical MR/iMRI: the first MR-guided craniotomy; the first helnum free super-conducting magnet design; the first combined intraOp/interventional/diagnostic MR capabilities; the first combined MR/X-ray system; the first real-time MR image guidance; and the first MR platform used to perform over 15,000 intraOp/interventional procedures. Today, GE Healthcare has the largest fixed intraoperative MR/iMRI installation base and by working with companies such as MRI Interventions, the future is bright to continue pushing the possibilities of intraoperative MR further.

In August 2014, Dr. Chen performed three same-setting MR-guided neurosurgical procedures for a single patient using the ClearPoint® System. He biopsied a patient’s brain tumor, aspirated a fluid-filled section of the tumor, and ablated the tumor, all under real-time MR guidance. Using the ClearPoint system for the biopsy, Dr. Chen was able to see and select the tumor at its location within the brain, establish the desired trajectory to the tumor with MRI Interventions’ SmartFrame® targeting device, and visualize the biopsy needle as it was inserted into the desired region of the tumor, confirming with real-time MRI that the sample was removed from the targeted location. Next, Dr. Chen was able to adjust the trajectory in order to aspirate a fluid-filled section of the tumor, monitoring the tumor’s changing size and shape under MRI guidance as the fluid was removed. Dr. Chen then utilized the ClearPoint system to target the reduced tumor, visualize the placement of a laser catheter as he inserted it into the tumor, and confirm placement of the catheter at the desired location for ablation. Finally, when intraprocedural MR showed that a portion of the tumor was irregularly shaped, he was able to once more adjust the SmartFrame targeting device to reposition the catheter so that he could ablate the final segment of the tumor.

Karl Sillay, MD, FAANS, is an Associate Professor, Department of Neurosurgery at the University of Tennessee, Memphis. Dr. Sillay also has surgical privileges in the iMRI suite at the University of Wisconsin Hospital in Madison. Dr. Sillay received his Medical Degree in 1999 from the Medical College of Georgia, completed his Internship at Vanderbilt University, and also his Neurosurgical Residency, which he completed in 2006. In 2007 Dr. Sillay completed a Fellowship in Epilepsy and Functional Neurosurgery at the University of California at San Francisco.

University of Wisconsin Hospitals and Clinics is a 566-bed facility that ranks among the finest academic medical centers in the United States. Frequently cited in publications listing the nation’s best healthcare providers.

Clark Chen, MD, PhD, is Chief, Stereotactic and Radiosurgery, Vice Chairman Neurosurgery, and Associate Professor of Surgery, UC San Diego School of Medicine. Dr. Chen received his B.S. in Biology from Stanford University, his M.S. in epidemiology from Columbia University, and his MD and PhD degrees from Harvard Medical School. He subsequently completed his neurosurgery training at the Massachusetts General Hospital, including a clinical fellowship in radiosurgery and a second fellowship on stereotactic neurosurgery. Dr. Chen is the co-Principal Investigator of the UCSD Center for Theoretical and Applied Neuro-Oncology (CTAN).

At UC San Diego, the Neurosurgical Service continuously staffs medical facilities at UC San Diego Medical Center-Hillcrest, UC San Diego Medical Center-Thornton campus, the VA medical center, Rady Childrens Hospital, and Palomar Hospital Locations. Thirty-one neurosurgeons, 14 of whom are residents-in-training, are on the staff.
In today’s competitive, cost-contained medical imaging environments, hospitals and group practices want to get the most out of their technology investments. Longevity, productivity, and clinical excellence are all important considerations in maintaining capital equipment. MR systems are no exception. Yet, with an average product lifecycle that can span a decade, many facilities are faced with aging technology that can’t keep pace with today’s clinical imaging needs.

Eric Weinberg, MD,
is Medical Director at UMI and Associate Professor of Radiology/Imaging Sciences at the University of Rochester School of Medicine and Dentistry.

Like New
Upgraded scanners at UMI deliver advanced apps, redefine workflow, and help enhance staff productivity
University Medical Imaging (UMI) in Rochester, NY, recently faced this predicament. UMI is the only outpatient imaging facility in the area to have eight fellowship-trained radiologists affiliated with the University of Rochester School of Medicine and Dentistry. The practice was also the first in the community to offer 3.0T wide bore MR imaging and the first to bring ASiR™ low dose CT to the region.

According to Eric Weinberg, MD, Medical Director at UMI, the practice strives to bring together the excellence of academic imaging with the personalized service of an outpatient imaging center. “We compete at the highest service level and focus on reducing report turn-around times, while we simultaneously train residents and fellows.”

Of the five MR scanners at UMI’s two outpatient sites, three are from GE Healthcare. The first was a SIGNA™ HD 1.5T, installed in 2002. Two years later, UMI added a SIGNA™ HDxt 1.5T and in 2008, the facility implemented its first 3.0T system—a SIGNA™ HDxt 3.0T. The practice offers a variety of MR imaging service lines—musculoskeletal (MSK), body, oncology, neurology, and vascular.

On average, UMI performs 19,000 MR exams each year. However, with different magnets at different operational levels, it was difficult to maintain the same level of quality imaging across exams performed on different machines. It also created issues with patient scheduling, explains Michael J. Lechner, RT(R) (MR) CAPPM, Practice Administrator and Privacy Officer. “We were handicapped a bit with scheduling, as some patients and studies could only go on certain magnets due to the available sequences and capabilities. We couldn’t get to a point where we could fill the modality’s slots automatically; it had to be a more free-flowing manual scheduling process.”

Dr. Weinberg and Lechner knew it was critical to keep the scanners up-to-date. Yet, replacing five scanners wasn’t financially feasible. In today’s competitive market, with cuts to reimbursement and fewer discretionary dollars, Dr. Weinberg knew the practice couldn’t replace them all. Fortunately, through its Continuum™ program, GE Healthcare provides cost-effective upgrades that bring many of the latest enhancements to prior-generation MR scanners.

In early 2014, UMI upgraded all three GE scanners to the latest version available for SIGNA HD scanners—HD23.0. The goal was to enhance clinical quality and efficiency with a common platform, new sequences, and advanced software that would help open up new service lines.

The HD23.0 Continuum™ Pak delivers advanced applications and workflow improvements with a high-definition platform so clinicians can do and expect more than before. Redefined workflow automates tasks so technologists can be more productive, and new advanced applications provide clinicians with the excellent image quality, accuracy, and reliability needed for a confident diagnosis.
With three scanners to upgrade, UMI and GE staggered the process to have the least impact on clinical workflow. Lechner was impressed with the level of detail in GE’s planning, particularly the extra steps taken to look for and prevent potential issues. For example, because of the stronger sensitivity of HD23.0, it was vital to determine room integrity. A pre-installation inspection was performed and it was discovered the recessed floor required a change in the braces and shims. This was necessary to prevent vibration, which would have a negative impact on image quality. This pre-inspection resulted in floor repairs being completed in advance to optimize the upgrade process which also had a positive result moving forward with applications. Additionally, the applications training was interspersed so the staff had time to learn the new features.

“The entire process was exactly as planned with no surprises by a very professional, very dedicated team,” Dr. Weinberg adds.

**Spectacular imaging**

Even though the magnets remained the same, nearly everything else changed with the newly upgraded systems. Dr. Weinberg immediately saw the difference in the MSK studies as he was able to use IDEAL—which provides robust, homogenous fat/water separation even in difficult to scan anatomies—on all three GE scanners. For MSK, IDEAL also helps preserve image integrity and suppress fat in areas of high magnetic susceptibility. “IDEAL was one of the key benefits… with the knees it is very impressive,” he explains. The practice performs more than 5,000 MR knee exams each year, and it relies on this sequence to generate the high-quality images of the ligaments and surrounding tissues that orthopedic surgeons need for treatment planning.

In addition to achieving higher image quality with IDEAL compared to STIR...
Other significant improvements are the addition of PROPELLER 3.0 for motion correction in all body parts, fast spin echoes, and enhanced diffusion weighted imaging (eDWI). Dr. Weinberg continues, “PROPELLER is just huge for the technologists. It gives them an option... instead of telling the patient to hold still and repeat they can jump right in, run PROPELLER, and then move on to the rest of the exam. Also, we previously had issues with obtaining decent diffusion studies in the liver, and it’s a mainstay sequence for liver imaging so it has to be really good. Now, with the upgrade, it is. These are improvements that you can’t appreciate unless you see them.”

sequences, the practice was able to reduce a 22-minute exam by up to seven minutes, or 33%, to 15 minutes. Part of the speed from the upgrade is achieved by the use of ARC, a parallel imaging technique, and an 8-channel coil, “providing a whole host of new improvements in image quality and speed,” says Dr. Weinberg. “It’s the best scenario for us; we get better image quality in less time.”

The shorter exam time presents the opportunity to schedule three knee exams in one hour rather than just two, adds Lechner. “Now we have the potential to add volume, and we are already reaping the rewards. Plus, we can stay on schedule better if we have complications, such as metal implants or movement during the exam. Or if we have multiple knee scans, we can now squeeze them in or juggle patients around with a 15-minute slot compared to a 30-minute slot.”

In fact, Dr. Weinberg says the upgrades on the 1.5T magnets are so spectacular with the knees that he refers to the systems as 2.0T scanners. “With the high image quality, I can see cartilage in far greater detail with a higher imaging matrix, and we feel more confident in our ability to identify tears. Really, it’s just a remarkable improvement.”

Figure 2. Knee exam performed on SIGNA HD (A, B) prior to upgrade and with HD23.0 Continuum Pak post upgrade (C, D).
While Dr. Weinberg can’t quantify the time he saves reading higher image quality studies, he knows he is faster and more confident after the upgrades. No longer is he trying to look through motion artifacts or sub-optimal image quality.

“Operationally, we can perform exams more efficiently and our technologists are happier and more productive with the same platform across our three GE MR scanners,” offers Lechner. Patients are also happier with the shorter exams, and referring physicians are getting a new level of high-quality studies.

At the end of the day, Dr. Weinberg says, it’s all about doing what’s right for your patients. “We have an obligation to our patients and referrers to provide the highest level of imaging services. They should always be a very important factor when deciding to upgrade an aging MR system.”

**Eric Weinberge, MD,** Medical Director at UMI and Associate Professor of Radiology/Imaging Sciences at the University of Rochester School of Medicine and Dentistry. Dr. Weinberg specializes in Cross-Sectional Imaging in MR, CT, and Ultrasound. His in-depth knowledge of these sub-specialty areas results in a higher level of accuracy and care. As a professor and researcher at the world-renowned University of Rochester Medical Center, he also teaches the next generation of radiologists about the latest developments in the field.

As Medical Director, Dr. Weinberg personifies the philosophy of treating each patient with the highest level of competence and compassion. His deep level of experience provides both patients and their referring physicians with a high degree of accuracy, insight, and peace of mind.

Dr. Weinberg is currently working on a book about Musculoskeletal Imaging (MR) that will be a clinical guide for practitioners and students. He completed a fellowship in cross-sectional imaging at the University of Rochester Medical Center and a residency in radiology at Albany Medical Center. He earned his medical degree at Albany Medical College.

**Michael J. Lechner,** RT(R) [MR] CAPPM, Practice Administrator and Privacy Officer at UMI. Lechner’s entire career has been in radiology. A NYS-licensed Radiologic Technologist certified in MR, he has worked on the frontlines of his field, beginning in 1990 as a Staff Radiographer at the University of Rochester Medical Center. Michael came to UMI in 1996 and has served as UMI’s Lead MR Technologist, Chief Technologist and since 2005 has served as the Practice Administrator. Having worked with physicians and patients, he brings both clinical experience and practical business training to UMI.

In addition to a degree in Radiologic Technology, Lechner has advanced certifications in Leadership Development, Six Sigma business training, and Physician Practice Management. He is a member of the American Academy of Professional Coders, the American Registry of Radiologic Technologists, the American Academy of Medical Management and the Association for Medical Imaging Management.

**UMI** is the only imaging facility in the region to have eight fellowship-trained radiologists affiliated with the University of Rochester School of Medicine and Dentistry. As leaders in their field, they have advanced expertise in sub-specialties such as neuroradiology and musculoskeletal imaging. UMI was the first to provide digital X-Ray in an outpatient practice in their region, the first to bring low radiation dose CT to the Rochester area, and the first to bring high-field 3.0T wide bore MR to the community. UMI is ACR-accredited for higher standards of safety, accuracy, and quality.
Neuro surgery Institute is First in Russia to Use SilentScan Technology and Enhanced Applications

Neuro MR patients love the new sound of SilentScan at the Neurosurgery Institute, also known as N.N. Burdenko in Moscow, Russia. The center has four MR systems from GE Healthcare, including the Optima™ MR450w 1.5T with GEM technology. Thanks to an upgrade to its Optima MR450w, Burdenko Institute’s brain studies are nearly silent. This is made possible because of SilentScan—a neuro acquisition technique from GE Healthcare that makes MR scans virtually silent while still providing the excellent image quality that helps clinicians make a confident diagnosis.
Reducing noise, increasing scans

“We use SilentScan with patients requiring anesthetic support such as children, the elderly, those with neurotic disorders accompanied by phobias, particularly claustrophobia, or those with mental illness followed by disorientation. It allows us to potentially reduce diagnosis time and—in some cases—exclude anesthesia without loss of image quality,” says Kornienko Valery Nikolaevich, MD, PhD, Head of the Neuroradiology Department at Burdenko Neurosurgery Institute and Professor, Academician of Russian Academy of Sciences (RAS).

Pronin Igor Nikolaevich, MD, PhD, Professor at Burdenko Neurosurgery Institute and Corresponding Member of RAS, continues, “This is especially important while scanning pediatric patients, when anesthesia is associated with an increased risk of complications. For some patients we have reduced the procedure time due to our determination that pre-anesthetic training and post-anesthetic activities would not be required. These usually occupy up to 15% of the examination time. As a result, we increase the number of patients who receive MR scans.”

The upgrade to SilentScan has provided Burdenko Institute—the first facility in Russia to use this technology—with many benefits: a quieter environment and more relaxed patients, potentially leading to faster throughput with fewer rescans; elevated patient satisfaction due to a more pleasant experience; a quieter MR scanning room with less impact on noise levels of neighboring rooms; and innovative technology that offers a competitive advantage.

Figure 1. A 33 year-old with giant neurofibroma of the skull base and claustrophobia. SilentScan MR with contrast demonstrated the huge tumor in the middle cranial fossa and skull base with homogenous and strong enhancement.
Enhanced apps open doors

The DV24.0 Continuum™ Pak upgrade, recently installed on the facility’s Optima MR450w, has allowed Burdenko Institute to utilize many other enhanced applications—opening the door to research and quantitative MR studies. As GE Healthcare’s latest response to customers’ ever-changing diagnostic needs, the DV24.0 Continuum Pak offers a robust collection of solutions, in addition to SilentScan, to improve workflow and supercharge applications.

“Our Optima MR450w 1.5T with GEM technology now has the capabilities we need for carrying out neurodiagnostic procedures and surgical procedure planning. It allows us to perform sophisticated diagnostics using anatomical, functional, vascular, and quantitative research. With this upgraded system we now have the opportunity to evaluate the state of functionally important areas of the brain and study cerebral blood flow without intravenous contrast enhancement in the preoperative preparation,” comments Professor Kornienko.

Burdenko Institute is proud to be the first facility in Russia to utilize three enhanced applications: 3D Arterial Spin Labeling (ASL), FOCUS, and SWAN 2.0. Of particular importance for the facility’s clinical research of cerebral
hemodynamics is 3D ASL, which provides quantitative assessment of cerebral blood flow without radiation or need for contrast.

“We use the 3D ASL sequence to explore brain perfusion without use of a contrast agent. It’s also essential to our research of cerebral hemodynamics across a large group of patients who we prefer to not use contrast enhancement, such as patients with difficult venous access pathology and impaired renal function, including children and the elderly,” offers Professor Pronin. “Plus, we have found that mapping of cerebral blood flow speed with quantitative estimation opens new possibilities for studying cerebral microcirculation.”

Since the upgrade, FOCUS Diffusion (DWI) and FOCUS Diffusion Tensor (DTI) are frequently used at Burdenko Institute. FOCUS allows a technologist to zoom in on specific organs with DWI, improving image quality by removing artifacts related to motion, susceptibility, and fat—all common in large field-of-view imaging compared to non-motion corrected 3D acquisitions.

According to Professor Kornienko, FOCUS DWI became very useful for imaging small brain and spinal cord areas—without wrap-artifacts—in the construction of diffusion maps. He says the facility uses FOCUS DTI to build pathways of white matter of the brain (tractography) and obtain quantitative indicators of the degree of damage (diffusion coefficients and anisotropy).

Pronin Igor Nikolaevich, MD, PhD, is a Professor in the Neuroimaging Department at Burdenko Neurosurgery Institute.
Kornienko Valery Nikolaevich, MD, PhD, is Head of the Neuroradiology Department at the Burdenko Neurosurgery Institute, a professor, an honor scientist of the Russian Federation, and the author of 18 monographs on neuroradiology and more than 600 scientific publications.

Pronin Igor Nikolaevich, MD, PhD, is a Professor in the Neuroimaging Department at Burdenko Neurosurgery Institute and the author of 12 monographs on neuroradiology, as well as more than 300 scientific publications.

The Neurosurgery Institute, named after academician N.N. Burdenko, is one of the oldest neurosurgical clinics in Russia. Currently, Burdenko Neurosurgery Institute is the world’s largest clinic offering care for patients with diseases of the central and peripheral nervous system. For 76 years it has developed sustainable clinical and scientific traditions, providing a high level of MR diagnosis and treatment.

SWAN 2.0 is a high-resolution, 3D, multi-echo gradient echo sequence resulting in an SNR that is higher than a single-echo acquisition. It generates magnitude and phase images from a single acquisition, allowing differentiation between diamagnetic and paramagnetic products such as blood or calcium. “We use this new version of SWAN to receive images from the phase signal as well as from the amplitude signal that we then use to construct maps of the magnetic susceptibility for quantitative MR,” says Professor Pronin.

“Our experience with the upgraded Optima MR450w has allowed us to increase the level of comfort for our patients. It facilitates the technician’s work at the console and provides great image quality with reduced artifacts. Perhaps most important, the DV24.0 upgrade allows us to carry out research for children and severe postoperative patients—including those with various implants—as well as the elderly and restless,” concludes Professor Kornienko.

Figure 4. A 52-year-old with multiple cavernous angiomas of the brain. SWAN allowed clear visualization of multiple brain lesions. Only one angioma in the left temporal region would have been identified if the routine MR scan had been performed.
Introduction

Intracranial stenting in the case of coil embolization is a newly developed, promising technique for broad-neck or complicated aneurysms. Coils for aneurysm embolization usually result in minimal susceptibility effect. Thus, imaging assessment of a follow-up study after intervention can be performed by TOF-MRA. However, when stent-assisted coil embolization is performed, it is difficult to evaluate the flow and lumen within the stent.

Silent MRA is an almost soundless MR sequence acquired by ultrashort TE (0.016) and an ASL-like technique with subtraction. The ultrashort TE sequence reduces noise due to gradient switching. We have also found that the ultrashort TE helps decrease the susceptibility effect from a metallic stent. GE MR scanners may be used to scan MR Conditional and MR Safe implants.

In some cases, Silent MRA with ultrashort TE allows us to visualize blood flow and observe the signal within the intracranial stent. Previously, the signal within the stent was difficult to obtain due to strong susceptibility effects on any sequence of conventional MR.
MR technique

Status post stent (Enterprise VRD) assisted coil embolization for supraclinoid carotid aneurysm.

Findings

On TOF-MRA, the flow in the stent could not be visualized (Figure 1A). Silent MRA showed the flow in the stent at the supraclinoid portion of the internal carotid artery (Figure 1B). In addition, Silent MRA visualized the residual small lumen within the coil-embolized aneurysm neck (arrow), which was comparable with the catheter angiography (Figure 1C).

Discussion

In our preliminary investigation, we have found that Silent MRA could potentially replace TOF-MRA in several situations—such as follow-up assessment of stent-assisted coil embolization of intracranial aneurysms. In addition to ultrashort TE, we found the subtraction technique used in Silent MRA can help avoid presentation of a high signal hemorrhage which may lead to misinterpretation on the conventional TOF-MRA. Subarachnoid, intramural, and parenchymal hemorrhage are the pitfall of TOF-MRA because pathologies with T1 shortening present high signal on TOF-MRA. High signal from hemorrhage may obscure vascular abnormality and/or mimic vessels.

Silent MRA is very helpful and may play an important role in the follow-up assessment of stent-assisted coil embolization of intracranial aneurysms.

Shigeki Aoki, MD, PhD, is Professor and Chairman of the Department of Radiology at Juntendo University. He received his medical degree from the University of Tokyo and, in 1988, was a visiting fellow at UCSF under Professor Jim Barkovich. Dr. Aoki has worked in many fields of neuroradiology and has published several articles, including: 3D CTA of cerebral aneurysm (AJNR 1992), intracranial vascular wall (Radiology 1995), MRDSA of AVF vessel (AJR 2000), and diffusion MR and diffusion tensor tractography of the brain (Neurobiol Aging 2002).

The authors currently have an article in press in AJNR, titled, Assessing Blood Flow in an Intracranial Stent: A Feasibility Study of Magnetic Resonance Angiography using SilentScan after Stent-Assisted Coil Embolization for Anterior Circulation Aneurysms.

Tokyo’s Juntendo University was founded in 1838 with the goal of helping society through medical education and practices. These aspirations led to Juntendo Hospital, the first private hospital in Japan. Over the years, the institution’s experience and perspective as a place of higher education and clinical practice has enabled the University to play an integral role in the shaping of Japanese medical education and practices. Today, it continues to pursue innovative approaches to international-level teachings and research with the goal of applying the results to society.
Case Study | Visualization of Male Urethra

MR Technique for Aiding in the Evaluation of Male Urethral Stricture Disease

By Professor Victor I. Dombrovskiy, MD, PhD, Chair, Dept. of Radiology and Head, MR and CT Division; Professor Mikhail I. Kogan, MD, PhD, Chair, Dept. of Urology and Director, Institute of Urology and Nephrology; and Emma L. Banchik, MD, Dept. of Radiology, Rostov State Medical University, Rostov-on-Don, Russian Federation

Introduction

Urethral stricture is the narrowing of the urethra caused by injury-related trauma to the urinary tract, or a viral or bacterial infection that may cause decreased urine output. The condition is more common in men than women due to the increased length of the male urethra.¹

Retrograde urethrography (RUG) is a radiographic procedure commonly performed in males to image the integrity of the urethra and diagnose urethral stricture. However, RUG may suffer from distortion characteristics of X-Ray, as it cannot provide the clinician with information regarding the presence of spongiosfibrosis (scar tissue in the urethral sponge).

In the three cases presented, we compared MR dynamic spongiourethrotomography (MR DSUT) plus 3D MR urethrography (3D MRU) versus RUG plus voiding cystourethrography (VCUG) in the evaluation of urethral stricture. Radiological results were compared with histological data.

MR Technique

MR was performed with a SIGNA™ HDxt 1.5T using an 8-channel phased-array body coil. MR DSUT used a modified 2D Fast Imaging Employing Steady-State Acquisition (2D FIESTA) pulse sequence in the sagittal plane and 3D MRU used a

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is Chair of the Department of Radiology and Head, MR and CT Division at Rostov State Medical University.
3D Fast Recovery Fast Spin Echo-Accelerated (M3D/frFSE-XL) pulse sequence. These MR techniques are usually used for evaluation of the heart, great vessels, and biliary tract, respectively. MR DSUT was conducted during a retrograde injection of sterile normal saline (0.1-0.3 ml/s) via a Foley catheter into the urethra as well as during micturition. In addition, T2w images were collected in the frontal plane using a frFSE-XL pulse sequence. The penis was taped midline to the abdominal wall.

Compared with original 2D FIESTA, slice thickness was increased to 15-17 mm for total coverage of corpus spongiosum, posterior urethra, and surrounding tissues. The initial slice was repeated 200-250 times for 1 sec each. This pulse sequence was used with contrast enhancement.

TR, TEff, and NEX values of original M3D/frFSE-XL were decreased by 25-30% due to small field-of-view (FOV). The FOV of both pulse sequences was 28 cm with an acquisition time of 210 sec and 35 sec, respectively.

We assessed the following: urethral caliber and wall elasticity; the presence, localization, length and severity of stricture; and the extent of spongiofibrosis. RUG and VCUG were also performed with contrast (Ultravist, Bayer Schering AG, Germany).

Patient 1

A 42 year-old with inflammatory stricture of anterior urethra (bulbous portion).

Figure 1. Sagittal MRDSUT image during retrograde injection of sterile normal saline (A); sagittal 3D MRU (B) and oblique RUG (C) images. In 1A, stricture of bulbous portion (1), penile (2), bulbous (3), membranous (4), prostate (5) urethra portions, urinary bladder neck (6).
Patient 2

Traumatic stricture of anterior urethra (bulbous portion) in a 47 year-old.

Figure 2. Coronal T2w (enlarged image), frFSE-XL pulse sequence (A). Slice passes through the bulbar urethra. Moderate spongiosis (1) around the narrowed urethra (2) filled with saline; intact spongiform body (3); the corpus cavernosum (4). Histological slide of the resected urethra fragment van Gison staining X 40 (B). Fibrous tissue in the urethra wall (arrow); the urethra wall urothelium (dotted arrow).

Patient 3

Multifocus traumatic stricture of urethra (bulbous and membranous portions) in a 45 year-old.

Figure 3. Sagittal MRDSUT image during micturition after retrograde injection of 50 ml sterile normal saline (A); oblique VSUG image (B). Urethra narrowing in the membranous and bulbous portions (arrow); prestenotic expansion of prostate urethra portion before the proximal margin of the structure (dotted arrow).

Findings

Anterior and posterior urethra portions were reliably visualized using retrograde MRDSUT. It should be noted that an increase in injection speed to 0.3 ml/s was necessary to identify the membranous and prostate parts.

In the cases of anterior urethra stricture retrograde, MRDSUT and 3D MRU provided its delineation, length, and severity (Figure 1). The excessive pressure in the urethra channel due to manual, uncontrolled speed of contrast

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media injection was responsible for the false negative results using RUG. The 3D MRU image provides additional diagnostic information and is similar to RUG data, yet without inherent projection distortion characteristics of X-Ray. This image can also be very useful for urologists experienced in the interpretation of RUG results.

Spongiofibrosis is the primary cause of anterior urethra stricture. On T2w it yields a hypointensive MR signal compared with normal spongiosum tissue. Obviously, 2D FIESTA generates images, mainly weighted on T2. However, the frFSE-XL pulse sequence (acquisition time—210 sec) creates T2w with the best soft tissue gradient of contrast. Using these MR sequences, we were able to identify spongiofibrosis of varying severity around strictures (Figure 2). The MR images also helped us to visualize two additional conditions: There was a difference in connective (fibrous) tissue distribution around a stenosis of traumatic or inflammatory nature and the spongiofibrosis spread beyond the extent of the stricture. This information can be used to select the surgical approach. To detect such spreading, we synchronize MR data of 2D FIESTA (sagittal plane) and frFSE-XL pulse sequences (frontal plane) using the SIGNA HDxt software. In our experience with these subjects, X-Ray failed to detect spongiofibrosis.

Connective tissue formation in the prostate and urogenital diaphragm around the urethra is an end-stage of traumatic injuries and the initial stage of restriction. In MR imaging, it is well known that fibrous tissue, striated muscles, and the central zone of the prostate are essentially isoointense on T2w. To detect posterior urethra strictures, T2w was applied during micturition in addition to retrograde MRDSUT. Afterward, 3D MRU was performed. On MR, the principal indication of posterior urethra stricture is the presence of a prestenotic expansion before its proximal border (Figure 3).

Discussion

For these cases, we found the proposed combination of MR pulse sequences helps us detect urethra stricture disease and the degree of its severity. Because of MR’s inherent ability to visualize soft tissue, it is well-suited in this application. We have advantages over the X-Ray contrast of ionizing radiation and nephrotoxic contrast media. The method has successfully been used on a SIGNA HDxt 1.5T scanner for helping in our diagnosis of the disease, helping choose the tactics and extent of surgical intervention, and allowing us to monitor the postoperative period.

Future studies could compare the diagnostic capabilities of MR vs. ultrasound to aid in the detection of urethra pathology as well as the potential diagnostic value of contrast-enhanced MR for the potential detection of posterior urethra stricture as it increases the contrast between muscle, the prostate, and connective tissue. Other areas we would like to explore, are the possibility of using MR software for post-processing to construct the curve characterizing the elasticity change of the urethra wall.

Reference

Along with the increased prevalence of orthopedic implant surgeries is the need to evaluate injuries to the joint post-surgery, patient complications, and in some cases the integrity of the prosthesis or device. However, X-Ray and MR imaging studies were traditionally compromised due to the presence of metal-induced artifacts that can obscure anatomy and pathology. It has also been well documented that MR can more accurately detect bone loss compared to plain-film X-Ray.\textsuperscript{1,2}

MAVRIC SL is a sequence for imaging soft tissue and bone near MR Conditional and MR Safe metallic implants. We evaluated the use of MAVRIC SL in the presence of metal compared to a traditional 2D fast spin echo (FSE) sequence and conventional radiographs at 3.0T.

**Patient history**

A 58 year-old with bilateral total hip replacements. The left hip was a metal-on-metal hip arthroplasty and the right hip was metal-on-poly. The patient had symptoms of pain and swelling, however, plain radiographs of the pelvis showed no evidence of hardware complication. The patient was referred to us for MR imaging at 3.0T on a Discovery MR750 scanner with MAVRIC SL metal artifact suppression.

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**Parameters**

- **Frequency FOV:** 40 cm
- **Phase FOV:** 1
- **Slice thickness:** 4.0 mm
- **Frequency direction:** S/I
- **TR:** 4,000 ms
- **Flip angle:** 75
- **ETL:** 20
- **Frequency:** 384
- **Phase:** 256
- **Excitation mode:** Selective
- **RF drive mode:** Quadrature

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**Figure 1.** Conventional 2D T1w FSE shows significant distortion and obscures the surrounding anatomy of the left metal-on-metal hip arthroplasty (A). MAVRIC SL PD-weighted enables visualization of the soft tissues around both hips. Evidence of synovial thickening is apparent on the left hip (B). MAVRIC SL fluid-sensitive STIR shows evidence of synovitis on the left hip (C).
Case Studies

Garry E. Gold, MD, is Professor and Associate Chair for Research in the Department of Radiology at Stanford University. He is also Professor (by courtesy) in Bioengineering and Orthopedic Surgery. He received BS, MS (Electrical Engineering), and MD degrees from Stanford University, finishing in 1992. Dr. Gold did his residency training in Radiology at Stanford University from 1992-1998, including a postdoctoral research fellowship with Drs. Albert Macvosi and John Pauly in Electrical Engineering. He also did a clinical musculoskeletal radiology fellowship at UCSD with Dr. Donald Resnick. Dr. Gold joined the faculty at Stanford in 1999. Dr. Gold's research focuses on developing new methods for MR that improve diagnosis and treatment of musculoskeletal disease. His many contributions to the field include some of the earliest initial application of uTE imaging in musculoskeletal disease. His group has developed advanced methods for morphologic and physiologic imaging of articular cartilage, and along with Dr. Brian Hargreaves, improved methods for imaging around metal. His research has also developed new approaches for dynamic MR in muscle and joint motion, and application of MR-guided Focused Ultrasound in musculoskeletal disease. Dr. Gold is a Fellow and Vice-President Elect for the International Society for Magnetic Resonance in Medicine ISMRM.

Stanford University Medical Center provides both general acute care services and tertiary medical care for patients locally, nationally, and internationally. The hospital's mission is to provide excellent care for its patients who live close by, as well as for those who come from afar for treatment of complex disorders. Consistently ranking as one of best hospitals in the US by US News and World Report and serving as the primary teaching hospital for the Stanford University School of Medicine, the hospital plays a key role in the training of physicians and other medical professionals. It provides a clinical environment for the medical school's researchers as they study ways to translate new knowledge into effective patient care.

Discussion
Metallic implants cause severe disturbances of the static magnetic fields utilized for spatial encoding of MR images resulting in signal voids, ectopic hyperintensities, and geometric distortions of tissue surrounding the implants. The result is obscured pathology and a non-diagnostic study. These artifacts are present at all field strengths, but they're worse at high magnetic fields.

Compared to conventional FSE techniques, MAVRIC SL greatly reduces these artifacts at both 1.5T and 3.0T by utilizing a 3D FSE technique to acquire multiple overlapping volumes at discrete frequency offsets. With this approach, the volumes are free of through-plane distortions and limit in-plane distortions. Phase encoding is applied in the slice-selective dimension while a novel multi-spectral 3D generalization of the view-angle tilting enables slab selectivity to prevent aliasing. Then, a deblurring post-processing technique is utilized in the final composite image. The result is excellent SNR and image integrity near MR Conditional and MR Safe metallic devices for high diagnostic-quality studies.

As more people undergo total joint replacement surgeries or have other devices implanted, it is important to evaluate the surrounding tissue to detect complications or other injury resulting from the implant or procedure. MAVRIC SL is an excellent MR sequence at either 1.5T or 3.0T that helps to fulfill this need.

Findings
High bandwidth +/- 125 kHz FSE scans were performed, which were degraded by significant artifact, obscuring the left metal-on-metal hip anatomy. Coronal MAVRIC SL fluid-sensitive STIR sequences showed evidence of adverse local tissue reaction in the form of synovial wall thickening, osteolysis, and synovitis. This was not visible on the conventional FSE MR sequences. The patient eventually received a revision arthroplasty on the left side, replacing the metal-on-metal arthroplasty with a metal-on-poly.

References

Garry E. Gold, MD, is Professor and Associate Chair for Research in the Department of Radiology at Stanford University.

Figure 2. Plain radiograph of the revised (left) hip showing two metal-on-poly implants.
Beyond the Scan

Recently, there has been consolidation among healthcare providers—changing the dynamics of decision-making—and many new-market entrants from insurance providers to private equity companies. This, combined with other factors, is creating tremendous margin pressure for hospitals. Adapting to change is a must in today’s healthcare market.

GE Capital, Healthcare Financial Services—an affiliate of GE Healthcare—focuses on delivering optimal financing solutions to help healthcare providers acquire the capabilities they want today. At the same time, the solutions help maintain the financial and operational agility needed for the future.

“We provide customized financing solutions that help support and grow healthcare organizations. Our team of dedicated professionals specializes in healthcare equipment, combining deep financial acumen, healthcare industry expertise, and solutions flexibility to help make state-of-the-art technology accessible,” says David Dobson, Chief Marketing Officer, GE Capital, Healthcare Financial Services.

GE works with a full range of healthcare providers, from healthcare systems and independent hospitals to outpatient centers and medical practices. The equipment team has helped over 5,000 providers finance their capital equipment needs. Financing products available include:

**Leases:** Through a diverse portfolio of operating and capital leases, a wide array of structures and features are available to help optimize cash flow while maintaining the flexibility to stay current with technology.
Loans: Whether a medical center is expanding, upgrading, or driving IT integration, GE’s loan offerings can help improve cash flow and conserve reserves while maintaining financial agility.

Tax-exempt financing: With tax-exempt loans and private placement bond offerings, not-for-profit and municipal hospitals are provided with additional ways to finance their capital needs.

“As the economics of healthcare increased in complexity, GE Capital’s models for asset acquisition and risk transfer address the challenges faced by healthcare providers today and in the future,” comments Dobson. “From basic loans and leases, to more encompassing models that involve varying levels of risk transfer, a broad spectrum of solutions are available to help meet a facility’s desired appetite for change and risk management.”

Customized lease solution
A customized MR financing solution from GE Capital, focusing on technology management needs—inclusive of equipment and service from GE Healthcare—can provide many benefits to facilities. For example, it can provide greater flexibility to move in and out of technology over time, helping to mitigate obsolescence and utilization risks while helping to maximize clinical, operational, and financial performance.

An example is the case of a facility interested in obtaining SilentScan technology for three in-place wide bore MR scanners. Two Discovery™ MR750w scanners were owned, and an Optima™ MR450w was leased with GE Capital. The medical center’s decision to order the SilentScan upgrades was dependent on GE’s ability to reduce its overall MR operating costs. GE Healthcare and GE Capital partnered to recommend a strategy that focused on total cost of use, including equipment, service, and financing.

- For the two owned Discovery MR750ws: AP Refresh, which combines a GE Healthcare maintenance service contract with a system upgrade, provided viable monthly payments for SilentScan upgrades.
- For the leased Optima MR450w: a structured upgrade/renewal, including SilentScan, over a six-year term, which drove a significant reduction in monthly cash outflows compared to the original payment.

The cash flow savings from the Optima MR450w lease upgrade/renewal were enough to offset the AP Refresh payments required to upgrade the two facility-owned Discovery MR750w scanners. According to Dobson, the medical facility was very pleased with the solution and has applied a similar approach to its CT fleet.

A customized financial solution, with a focus on a facility’s technology management needs and incorporating various elements of risk transfer, can provide many benefits by providing greater flexibility while helping to mitigate obsolescence and utilization risks. Such a solution can help maximize clinical, operational, and financial performance today and into the future.

“With the evolving asset acquisition and risk transfer models, coupled with technology management solutions, GE Capital can help address our MR customers’ challenges. It starts with a deep understanding of those challenges, and then we—partnering with GE Healthcare—collaboratively create solutions inclusive of technology, service, IT, and financing to provide real solutions,” concludes Dobson.

Evolving asset acquisition and risk transfer models, coupled with technology management solutions

1. **Traditional acquisition models**: Basic loans and leases with lower level of risk transfer.

2. **Metrics-based models**: Usage Based Billing (UBB) and Reimbursement Based Billing (RBB) models which shift some utilization and/or reimbursement risk away from the provider.

3. **Strategic portfolio management**: Offers portfolio standardization while helping to address utilization, new project viability, and technology obsolescence concerns through alternative structures and technology refresh programs.

4. **Fleet asset optimization**: Comprehensive review of each asset and its impact on the overall imaging portfolio to create multi-year, customized plans which help to optimize an imaging fleet through rightsizing and redeployment.
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