3T MR imaging promises to extend radiology's reach

November 02, 2005 | Musculoskeletal Imaging [1], RSNA 2005 [2], MRI [3], Practice Management [4], Vendors [5]

Exquisite images of the brain, spine, body, and joints will adorn vendors' booths at the RSNA meeting, attesting to the benefits of clinical 3T. But, unlike the many ultrahigh-field MR scans that vendors have displayed in the past, most of these 3T images will come from systems designed for everyday clinical practice.

Three-T is no longer the province of academia, with its ready access to medical physicists and its penchant for medical esoterica. These scanners will account for one of every four high-field systems sold in the U.S. this year. This much-touted new benchmark for high-field MR is not for everyone, however, according to those who have applied it in routine clinical practice.

Specialized pulse sequences, coils, and protocols optimized for 3T deliver images as good as those from a 1.5T scanner, with equally fast throughput. But if the goal is to do as well as 1.5T or just a little better, there's no point in assuming the extra cost for 3T, said Dr. Dave Siker, a neurointerventional radiologist and director of Siker Medical Imaging & Intervention in Portland, OR. "If you are a general radiology group doing brains and knees for primary-care doctors, it's probably not worth investing another million dollars," he said. "But if you associate with specialists, as I do, where you are trying to provide high-end work, 3T absolutely makes a difference and gives you a significant competitive advantage."

Siker and his staff are reaching out to specialists who need better images or applications beyond the grasp of the current benchmark. Since installing the Siemens Trio in May, they have routinely found what could not be seen at 1.5T. MR angiography uncovered two dual arteriovenous fistulas in one month, indicating that these tiny pathologies were the cause of patients' tinnitus.

Orthopedists in central Florida refer patients with meniscal abnormalities of the knee to 3T centers run by Dr. Mark Shapiro, because 3T can distinguish between a tear that can be surgically repaired and mixoid degeneration, which cannot.

Shapiro and his group use 3T scanners from GE Healthcare at centers in Melbourne, Orlando, and Merritt Island. He is planning to open two more centers with 3T in the next 18 months. "We do some very sophisticated imaging, including perfusion, spectroscopy, diffusion tensor imaging, and a little functional, and it is all clinical," he said. "We are able to do thinner sections with higher matrices and produce more detailed scans."

Siker performs cerebrospinal fluid flow studies in patients with hydrocephalus, specialized sequences in patients with suspected Alzheimer's disease, and MR spectroscopy for brain tumors. He takes these cases, even when reimbursement is lacking, as first steps toward the future.

"Three-T offers a whole other dimension of studies that are spin-offs from my main studies today," he said. "This allows me to say to specialists, 'If you work with me, I can do what nobody else can.'" Siker's group has identified intracranial aneurysms and tumors that were either not seen or equivocal at 1.5T. They found a hypothalamic hamartoma in a child whose 1.5T scan was read as normal at a neighboring pediatric hospital.

"When we scanned at 3T, it became clear on thinner sections and higher matrices that there was definitely a tumor," Shapiro said. "The child has been successfully operated on and is now seizure-free."

Lankenau Hospital, a 350-bed facility near Philadelphia, uses its Philips 3T Achieva for the most challenging cases, such as cardiac MR and spectroscopy, whenever possible. Routine cases, however, are just as likely be scanned on the Philips 1.5T system.

"We are a busy hospital, doing 600 MRs a month, so if the 1.5T is open and the 3T is being used, the patient is going to the 1.5T," said Dr. Andrew Curtin, a staff radiologist at Lankenau Hospital Imaging Center.

About 10% of patients at Lankenau are scanned only at 1.5T because dielectric effects at 3T cause
artifacts in the liver, Curtin said. Artifacts also occur in patients with ascites or a lot of bowel movement. And there are safety concerns.

"We'll do any coronary stent on the 1.5T but not the 3T," he said.

Three-T is probably safe, but the documentation and experience are still lacking, he added. Companies have developed advanced coils and workarounds to solve many of the problems associated with 3T: higher energy received by patients, reduced tissue contrast, increased magnetic susceptibility, and greater chemical shift. Many of these products are built into new 3Ts. More are on the way, but their use requires above-average skills.

"You definitely need to baby-sit 3T more," Siker said. "It is more like a Ferrari than a Ford, and your techs need to understand the physics better. You can't have an average MRI tech running this thing."

An increasing flow of information among 3T users and training from vendors help technologists. Siemens has worked individually with new owners and planned to hold its first 3T training course this month for customers considering the transition to the higher field.

"We want them to understand how they have to think differently about 3T," said Christopher Boyea, Siemens' ultrahigh-field marketing manager. "We'll look at key areas that are different between 1.5T and 3T."

Philips is disseminating information through "ExamCards," optimized 3T protocols for specific exams that can be downloaded onto any 3T Achieva. The cards are available from Philips' user Web site or directly from users. At the RSNA meeting, the company will introduce software built into the 3T Achieva that helps automate scan preparation and execution.

"Specifically, this will streamline workflow and provide an easy-to-use scanning environment," said Steve Mitchell, Philips director of marketing for MR.

The company will boost the performance of its 3T Achieva platform with new techniques based on Philips' SENSE (sensitivity encoding) parallel processing. KT-SENSE, its next generation in dynamic imaging, is scheduled for unveiling at the meeting. It exploits properties in both time and k-space domains to increase temporal resolution, Mitchell said. This will speed acquisition up to 35 frames per second for cardiac function exams, capturing the entire heart in a single breath-hold.

A combination of SENSE with Keyhole, a partial k-space sampling technique, and CENTRA (contrast-enhanced MR angiography), a random centric phase-encoding technique, will enhance 4D imaging by a factor as great as 60, he said. New SENSE-related capabilities will bolster spectroscopy, with a potentially dramatic effect on volumetric chemical shift imaging (CSI).

"This will allow volumetric CSI studies in very practical times, taking a 12-minute exam down to one minute. It could certainly be applied in the brain, but really there are no limitations. As long as you have a SENSE-compatible coil, you can use it anywhere in the body," Mitchell said.

Philips and GE claim to have all the coils any user needs. Siemens reached this level by adapting its TIM (total imaging matrix) body coil technology, developed for 1.5T, to its Trio scanner.

Siemens will highlight its next generation of coils and the system architecture to support them. Engineers are now developing a 90-channel head coil, Boyea said. The company will also talk up VERSE (variable rate selective excitation), a work-in-progress for fast spine echo imaging that will allow the application of multiple sequences.

Several products, including Siemens' Blade and GE's Propeller, will feature advances in motion compensation that particularly address radial movement. GE developed Propeller for 1.5T and is trickling that technology upward to 3T.

Such computing-intensive applications rely on GE's Excite HD (high-definition) data pipeline, released for 3T last year. The HD version adds the bandwidth needed for advanced clinical applications, as do similar technologies from Siemens and Philips. Excite HD will help users handle new coils designed with more channels to support extended applications.

"If you have any reservations about the clinical efficacy of scanning at 3T, what you will see in the GE booth this year will completely dismiss those reservations," said Bronwyn Medley, GE's global 3T product manager.

GROWING SALES

The continuous stream of innovations has buoyed 3T sales. More than 80 units shipped to U.S. sites last year, nearly double the number in the previous year. These scanners accounted for about $175 million, up markedly from the previous year's record revenue of $90 million. Vendors expect the adoption curve to rise further this year, as U.S. customers take delivery of more than 100 units.

The added power comes at a price. On average, 3T scanners cost over $2 million. A fully equipped 3T scanner can run as high as $2.5 million. But the increased signal to noise is worth the price, if radiologists can take advantage of it, Siker said. Three-T translates into substantially better functional MR studies, producing up to a 40% increase in the number of detected brain activations.
with blood oxygen level-dependent imaging, compared with 1.5T. The result is a higher success rate for presurgical mapping of the brain cortex associated with sensorimotor and language functions and the potential to evaluate patients for dementia and psychiatric disorders.

MR spectroscopy stands out among applications that are improved at 3T. The vast increase in chemical shift boosts spectral resolution, identifying metabolites that might not register at 1.5T. Time-of-flight MR angiography improves so much at 3T that the results of MRA rival those obtained with digital subtraction angiography, Siker said.

"I tell clinicians that diagnostic (x-ray) angiography is dead; I'm telling them not to do it," he said. "The vascular imaging at 3T from head to toe is so exquisite, there is no reason to do diagnostic angiography other than for interventions."

Magnetic susceptibility can be a problem at 3T, as at any field strength, when different types of tissue, such as temporal bone and brain, interface. But it can be helpful as well, as in the diagnosis of tendinitis, which is characterized by calcium deposits in the tissue.

"At 3T, that calcium will be more apparent because of its magnetic susceptibility," Medley said.

In echo-planar imaging, magnetic susceptibility can cause some distortion at this interface. Parallel imaging provides a way around the problem because it allows the echoes to be spaced out. Radial acquisition techniques such as GE's Propeller completely eliminate effects from magnetic susceptibility, Medley said.

**SOLVING PROBLEMS**

Some problems associated with 3T are easy to fix. In the case of contrast-enhanced 3T MR of the brain, Curtin simply cuts the dosage in half; otherwise, the contrast agent that remains in circulation would overwhelm the images.

Other solutions are more taxing. Pulse sequences have to be modified to get the best images from 3T and to keep patients from absorbing too much energy.

"This is where you go down a dark path into k-space and para-secret terminology; into the bowels of MR physics," Medley said.

Specific absorption rate (SAR) haunts 3T. Doubling the field strength from 1.5T to 3T quadruples the energy and causes increased tissue heating. The FDA has set a limit of 8 watts per kilogram of body weight for any five-minute period and 4 W/kg for a whole body averaged over 15 minutes. Adhering to those parameters had an adverse impact on early performance.

"Many of the early rumors going around about 3T acquisitions taking longer than 1.5T were driven by poor SAR management," Medley said.

The vendors have since redesigned radiofrequency chains in combination with acquisition techniques to overcome problems associated with SAR. GE has adjusted its magnetization transfer prepulse, which is energy-intensive, to focus on the center of k space. This change achieves the kind of tissue contrast necessary but does not overload the patient with energy.

Tissue contrast is an issue because 3T prolongs T1 relaxation times while shortening T2 times, causing problems in traditional spin-echo acquisitions involving short TR and short echo time.

"This makes cerebrospinal fluid gray rather than dark, but you can get around that by using different pulse sequences," Shapiro said.

Operators may prefer to use inversion recovery methods because they preserve tissue contrast at 3T. FLAIR (fluid-attenuated inversion recovery), which works well at 1.5T, may impose too great an energy burden at 3T. But inversion recovery sequences can be fine-tuned for specific applications. Philips suggests SPAIR, a 3T-specific technique that offers fat suppression over large fields-of-view. It may be especially helpful for breast imaging but can also be applied in body imaging. The technique is an adaptation of SPIR (selective partial or spectral prepulse inversion recovery). There is no consensus on what "SPAIR" actually stands for, but its similarity to SPIR helps technologists remember its application.

"At 1.5T it's SPIR, and at 3T it's SPAIR," Curtin said. "The vendors try to keep this stuff similar so our techs don't have any issues with it."

**HARDWARE FIXES**

Certain challenges arise from the physical design of the magnet. Shortening the length of the scanner reduces the number of wire windings around the electromagnet, which in turn affects the homogeneity of the field.

GE claims to have developed a proprietary solution to this problem: building magnets that maintain homogeneity despite their shorter length.

"We have completely changed the inside design of the magnet, and it maintains the number of windings that we need to get good homogeneity," Medley said, though he refused to elaborate. Siemens has placed more emphasis on homogeneity than magnet length, according to Boyea.
"We focused on maximum homogeneity in the biggest patient acceptance environment," he said. The Siemens Trio with TIM offers homogeneity of one part per million across its 50-cm field-of-view, which is the highest homogeneity in the industry, Boyea said.

Acoustic noise can be a problem, reaching twice the level at 3T as at 1.5T. Gradients bang and knock with increased ferocity in response to the added power applied to them. Vendors have tried several routes to get to the root of this problem.

Philips has implemented a "force balanced" design for 3T that minimizes the thrust that occurs when gradients are energized. The company also reduces the noise with software that manipulates the gradient profile shape, Mitchell said.

"With this, we can reduce acoustic noise to slightly louder than 1.5T," he said. Siemens uses a special epoxy resin to keep gradients in place, decreasing acoustic noise by up to 20 decibels. A software feature similar to Philips' reduces noise further.

"Now you can actually walk into the 3T room and not need ear plugs," Boyea said.

Damping the noise with software, however, comes at a price. This software "derates" the pulse sequence by shortening the TEs and TRs, which stretches the echo spacing for fast spin echoes. The end result is a quieter but longer acquisition.

"It is not something you would want to employ every day, but you might want to use if somebody is extremely sensitive," Boyea said.

Staff typically give patients ear plugs or headphones for music, or they apply noise cancellation techniques. The benefits from the use of 3T far outweigh the problems, which are becoming less of an issue with vendor workarounds. Scanning at 3T remains sufficiently challenging, however, that even Shapiro, one of the staunchest proponents of this technology, advises caution.

"I don't recommend that radiologists who are novices in MR buy 3T at the present time," he said. "To get the best out of 3T, you have to be familiar with the physics of MR. Or you should wait until all this becomes cookbook."

Greg Freiherr, business editor for Diagnostic Imaging.

Source URL:
http://www.diagnosticimaging.com/musculoskeletal-imaging/3t-mr-imaging-promises-extend-radiologys-reach

Links: