SPECIAL

visions

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Intelligent MRI in the AI Era

Canon

Cover Image:
Shutterstock and Canon Medical Systems' clinical images, including selected images with Advanced intelligent Clear-IQ Engine (AICE). AiCE is the world's first fully integrated Deep Learning Reconstruction technology for MR. Read more about this technology in this VISIONS magazine.

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Editors
Robb Mackenna
Sawami Takano
Ayumi Fukuda

Design & Layout
Natsumi Atou
Kenji Abe

Text contributions and editing
Mélisande Rouger - Independent Journalist
Sara Sharp - The Creative Practice

Contact us:
visions-mr@medical.canon

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// EDITORIAL

The heart of Toshiba, the spirit of Canon

Moving MR Forward in the age of AI with clever applications that bring true value to our global partners

Does Canon make MRI?

This was the surprising and most common question many Canon employees received globally when promoting our MRI technology to customers in 2018. Following Toshiba's sale of their medical division to Canon in 2016, the company name officially changed to Canon Medical Systems in 2018. The challenge in front of us was that with a new name Canon MRI was not on the top of mind for many people in the MRI community. Now in our 3rd year as Canon, we feel that the people who knew that Toshiba was an important contributor to MR imaging appreciate that Canon is now taking that ball and running hard into the future.

We believe strongly Canon MRI is truly exciting many people in the MRI community. Because not only has Canon MRI inherited an outstanding base of MRI knowledge and technology from Toshiba, in the past few years we have been actively enhancing our technology line-up with a string of acquisitions in the MRI space, topped off with the ability to now produce our own MRI magnets. And this does not even account for the leading position that Canon has taken in the Artificial Intelligence space, which not only boasts the world's first deep learning technology for MRI, but also utilizing AI across our entire medical imaging portfolio. We are convinced the ability to use AI to remove noise and improve image quality has persuaded many clinicians globally to take another look at how AI can improve healthcare, and in turn has placed Canon MRI at the front of the pack in this exciting area. And for us, the value of AI in diagnostic imaging is only just beginning, we are now utilizing the knowledge we have gained and feedback from our clinical partners to consistently advance forward on many more applications to help our customers image more intelligently and efficiently.

The vision we hold within Canon MRI to improve the life of patients in partnership with our clinical partners has never been clearer. MRI plays a critical role in diagnostic decision making, yet is still unavailable in many parts of the world due to the size and cost, let alone the clinical and technical education required to operate an MRI machine. Yet we know that the ability to image without radiation is vital to patients and radiologists alike, and we have a burning passion to widely expand MRI to support Canon's Made for Life philosophy.

At this time of enormous social change brought about by the events of the past 12-18 months, we believe strongly that the contribution that Canon MRI is making, and will continue to make, is more important than ever to the vital work that our clinical partners perform every day.

We are very proud to bring this MRI special edition to you to introduce key developments we have been working on, and I welcome you to take another look at Canon MRI. We hope you will be surprised by what you find, and that Canon MRI becomes a name known by every medical institution due to the value that we offer. We look forward to continue to walk on this journey with you as we forge our own footprint in this important imaging modality, driven by what we call Intelligent MR performance.

Akira Adachi
General Manager, MRI Systems Division,
Canon Medical Systems Corporation

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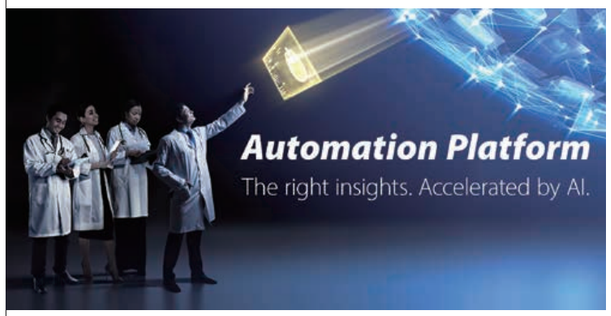

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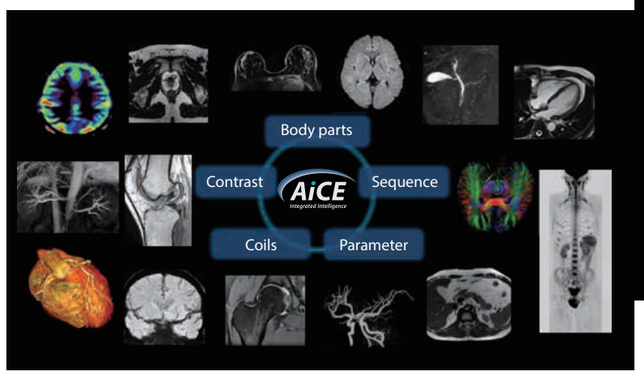

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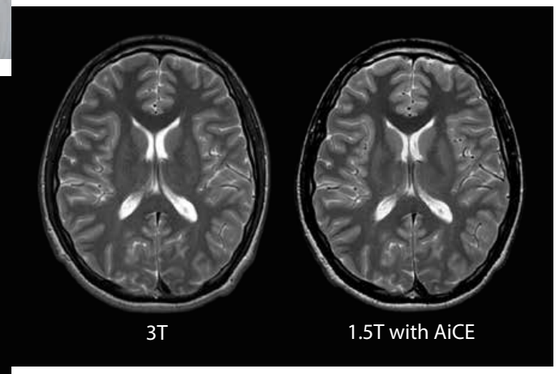

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Advanced intelligent Clear-IQ Engine (AiCE)
GOOD TO KNOW

Something for Everyone: Introducing Canon's Comprehensive and Easily Upgradeable MRI Line-up, Boosted by AI

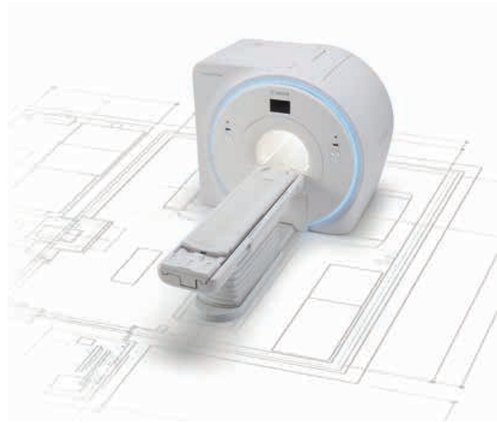
The world of magnetic resonance imaging (MRI) is one of the most challenging in terms of technical prowess and appropriate investment in the right technologies. Over many years of our participation in the MRI field, Canon Medical Systems has been steadily increasing our focus on both, with a recognition that MRI is a modality with tremendous potential to impact medical diagnosis. Recently we have sharpened our view on to what we call the three C's; representing "confidence" in our systems and the clinical results they produce, "comfort" that helps us focus on patients and the feeling we want them to have when being scanned by a Canon MRI system, and "cost-effective" meaning the economic value that our systems bring to facilities from installation through to operation.

In relation to these core goals we are developing technical solutions that we believe can unlock the true value in these three C's. From a very fundamental level, the technical evolution is towards solutions that deliver high SNR, high resolution and faster scanning, which everyone who scans in MRI understands are the absolutely unconditional yet often conflicting elements of effective scanning. Traditionally these three areas can be juxtaposed against each other and trade-offs must be made, however at Canon we are aiming for MRI where all of these solutions can live in harmony with each other to produce an MRI experience that has not yet been achieved before. We understand these are lofty yet worthy goals, and underpins what drives our efforts every day.

So how are we achieving this? The simple answer is what we call "intelligent MRI", which not only encompasses the exciting new frontiers of artificial intelligence, but also the relentless pursuit of smarter ways to optimize every aspect of the MRI experience. We believe intelligent MR can deliver three concrete outputs for the MRI suite. The first of these outputs is the oft spoke of "productivity", because we recognize that the nature of health care cannot only be for the sake of health care alone no matter how important, it must also deliver a bottom line performance element that is always the unavoidable remit of the C-suite executive. Without an economic case that is attractive to Healthcare facilities, we do not have the chance to deliver the second of our key outputs which focuses on safe, comfortable and quantitative imaging for the patients. Patients deserve the most secure environment possible, however should also have confidence that the results are delivering definitive and quantifiable diagnostic results that can help them understand the condition that brought them to the MRI suite in the first place. And finally, our third output is what could be considered the most important, improving the morale and confidence for the operator in meeting the ever tightening budgets and time-slots that are imposed upon them by the reduction in reimbursement. It is Canon's strong belief that Intelligent MR solutions can deliver on all of these promises without compromise.

Canon has developed outstanding platforms in 3T with our research level Vantage Centurian, which delivers advanced technology that now benefits our primary 3T clinical system, the Vantage Galan 3T. Both of these systems are forging new frontiers in the 3T space, and are recognized for their clinical utility and clarity in Neuro and MSK and particularly effective in diffusion imaging due to their high gradient performance. Our flagship 1.5T system in the wide-bore market is the Vantage Orian, which has made quite a splash since its launch in 2018 with a focus on productivity for the routine imaging suite that also needs to be able deal with challenging patients and advanced applications. We also offer a standard bore system in the 1.5T market, the Vantage Elan, which is one of our most successful systems ever, recognized for its outstanding imaging capability, small footprint and cost effective operational performance. We are also proud to say that every system in our range now offers AI boosted Advanced intelligent Clear-IQ Engine (AiCE) noise removal technology which delivers clear images and restores SNR, and compressed sensing and parallel imaging scan acceleration technology. We believe with a suite of intelligent technologies, and with many more to come, that we can deliver on our promise of the "three C's" make our clinical partners lives easier so they can focus on the most important person; the patient in front of them.

In these challenging times of COVID-19 when as a global medical community we must come together to provide ever more effective health care, we welcome you to experience Canon MRI solutions from this new perspective of Intelligent MRI.



Canon

// PORTFOLIO

3T MRI

Cross over to a new era of MRI with a 3T system fully capable of meeting the imaging needs of a cutting-edge healthcare facility.

Vantage Centurian

Vantage Centurian is an Ultra-high resolution research-enabled 3T MRI system that provides outstanding image quality without compromising on features or performance.

• "Inspire" empowering research with high performance hardware

High gradient performance of 100 mT/m and 200 T/m/s with a stable gradient coil design can support advanced research activities. Vantage Centurian's gradient capability enables extreme scanning conditions to meet higher requirements and the ability to expand to a variety of research focused applications.
Canon's PURERF offers enhanced SNR through unique noise-suppression technology which reduces the electrical noise received with the MR signal. High-performance amplifier and digitizer for each receiver produces faster sampling which results in higher SNR.

• "Explore" with intelligent imaging applications

Utilizing Advanced intelligent Clear-IQ Engine (AiCE), Vantage Centurian's advanced MRI technology offers your referring physicians and patients the best 3T MRI services available. AiCE is the world's first fully integrated deep learning reconstruction for MR, which is built directly into the scan protocols for seamless workflow. Producing stunning MR images that are exceptionally detailed and with the low-noise properties you expect of a high SNR image.

Vantage Centurian

Vantage Galan 3T

Vantage Galan 3T offers a transformational experience for you and your patients in 3T Magnetic Resonance Imaging. By prioritizing the patient experience while delivering the 3T imaging performance you expect and the clinical workflow you need to support a busy MRI environment, Vantage Galan 3T is designed to surpass your expectations – all delivered in a compact and quiet 3T MRI system.
Vantage Galan 3T from Canon evolves into the AI era with Advanced intelligent Clear-IQ Engine (AiCE) technology and fast scanning without compromise with Compressed SPEEDER. Combined with outstanding automated workflow, pure digital image quality, and industry leading patient focused design, Vantage Galan 3T is the MRI system you need now, and into the future.

• Outstanding resolution with Deep Learning

This unique 3T system produces the exceptional performance with the AI boosted technology. This intelligent technology enables increased resolution or decreased scan time much more than that is expected as 3T systems.

Vantage Galan 3T

• Intelligent technology to advance productivity

Reducing scan time improves the patient experience and increases throughput. With intelligent technology that advances our rapid scan technology, Vantage Galan 3T delivers productivity that goes beyond expectations.

Our rapid scan technologies; Compressed SPEEDER, Fast 3D and conventional parallel imaging covers various 2D/3D scanning in daily routine procedures. Furthermore, intelligent workflow enhancing technologies with EasyTech solutions and ForeSee View can help improve throughput.

• Delivering a comfortable MRI experience

A relaxed patient is key to enable stable MRI images. The short magnet and 71 cm bore offers an open MRI scanning environment. Our Pianissimo technology delivers whisper quiet scanning and the MR Theater relaxes patients with a virtual immersive experience.

1.5T MRI

1.5T is still the most common MR system used globally. Under the current challenging situation, Canon MR are focusing on high productivity, patient comfort and clinical confidence with our 1.5T portfolio.
We have two types of 1.5T systems: the Vantage Elan with a 63 cm bore and Vantage Orian with a 71 cm wide bore.

Vantage Orian

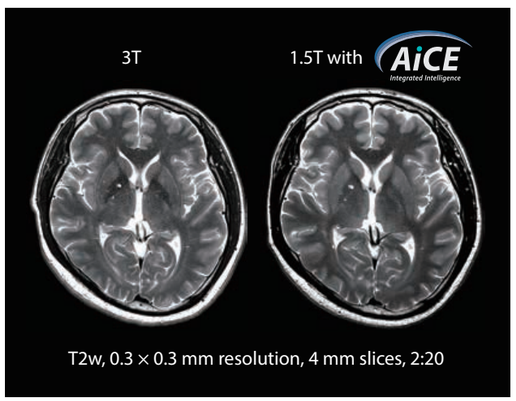
Step into the AI era with Vantage Orian to boost your MRI imaging performance and productivity at 1.5T. Focused on supporting exam efficiency and handling complex patient sets with Artificial Intelligence designed to accelerate exams and deliver clear images, Vantage Orian is the perfect balance to your 1.5T MRI business and clinical requirements.

Vantage Elan / NX Edition

Now available with Artificial Intelligence (AI) based noise removal and compressed sensing scan acceleration technology inherited from our high-end MRI scanners, Vantage Elan delivers operational and clinical freedom on every front. Vantage Elan / NX Edition delivers next generation MRI in a compact system with best in class power consumption.

• Alleviate the fundamental tradeoffs of MR theory

As a first step, Canon MR aimed for achieving high SNR comparable to 3T MRI by using 1.5T MRI to alleviate the fundamental tradeoffs between SNR, scan time and resolution.
In MRI, there are inherent tradeoffs between signal-to-noise ratio, scan time and resolution due to limitations imposed by MR physics.
For example, higher SNR and resolution are desired for better image quality and higher diagnostic confidence but they often come at the cost of longer scan time. Using higher field strengths is one of the approaches to reduce the inherent tradeoffs.
However, imaging at higher field strengths has several challenges such as higher equipment and operating costs, increased safety risks due to higher heat deposition to the patient, and increased image artifacts due to higher field inhomogeneities.
Advanced intelligent Clear-IQ Engine (AiCE) is the world's first Deep Learning Reconstruction technology for MRI. AiCE has the potential to alleviate the fundamental tradeoffs of MR.

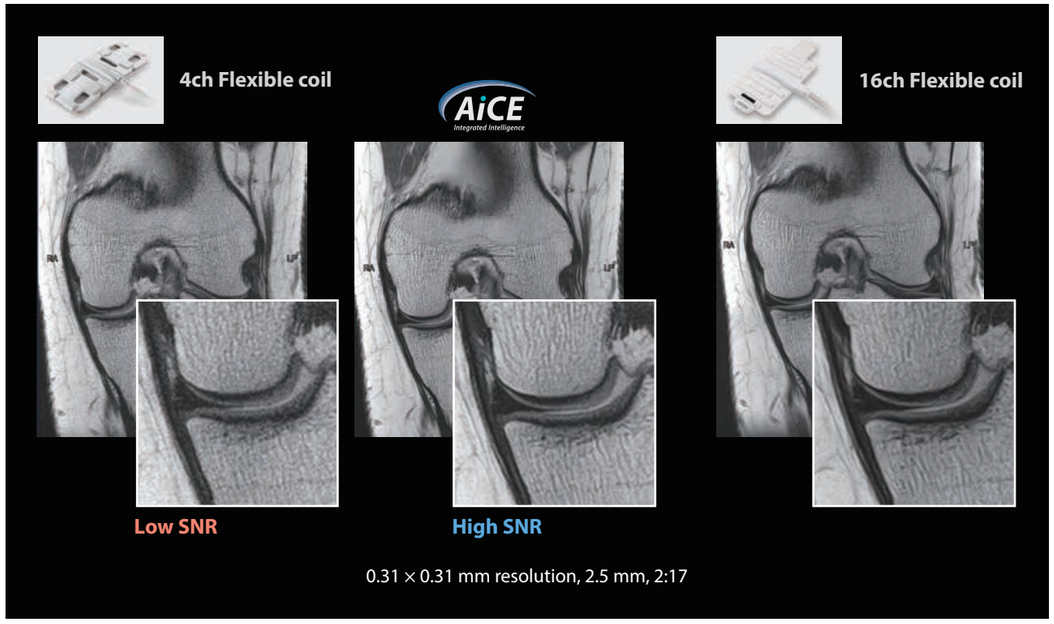


AiCE operates independent of anatomy, contrast, sequences, coils and parameters. And AiCE removes only gaussian noise so that you can also use it for quantitative imaging. Regarding coils, high channel coils can achieve higher signal than low channel coils. When using lower channel coils, you need more scan time to increase SNR.AiCE will improve SNR of images by using low channel coils without changing parameters.

By harmonizing the trade-offs in MR imaging, we believe that AiCE will definitive strong value for your hospital operations.

Vantage Orian

Vantage Elan



The right-hand side image was scanned using a 16ch Flexible coil and the left-hand side image is scanned using a 4ch Flexible coil. Normally, images from a 4ch Flexible coil will have lower SNR than a 16ch Flexible coil's image. However in this example you can see similar quality images without increasing scan time compared with a 16ch Flexible coil's image.

• Smart investment choice
Canon Magnets can often be installed in the same space as a room that contained a permanent system without significant modifications. In particular, Vantage Elan is one of the smallest MR systems with a compact footprint[1] of 23 m^2 and an additional control room is NOT required. Vantage Elan is designed around the concept of compactness. In addition to the reduced system size, the installation method, cooling method and control cabinet have been innovatively redesigned to minimize space and cost.

Vantage Orian requires 25 m^2 and the scan room requires only 16.4 m^2.
Small footprint is one of the solutions for reducing construction costs while maintaining your operational needs.

• Comfortable scanning environment.
Pianissimo technology significantly reduces the noise in and around the MR environment for every patient, every sequence, every time. Pianissimo Zen quiet sequences further reduce noise to just above ambient noise level, making exams even more comfortable and easier to complete. Vantage Orian and Vantage Elan / NX Edition deliver whisper quiet exams with Pianissimo, Pianissimo Σ and Pianissimo Zen.

[1] *the minimum footprint may not be applied in some cases depending on each sites situation.*
[2] *depending on the condition of usage and examination.*

Encore Upgrade

It is now possible to upgrade many existing Canon systems to a Vantage Orian or Vantage Galan 3T which will allow your facility to experience cutting-edge clinical performance with the latest MR technology.

Why consider and Encore Upgrade?
- Ability to keep your current magnet so that the initial cost will be minimized
- Ability to reduce downtime compared to a brand-new system installation so that you can restart the daily examination sooner
- Ability to make the move to a new digital platform so that the system can be operated with the latest technology
- Opportunity to get access to the latest technologies, such as Deep Learning Reconstruction and Compressed SPEEDER so that you can achieve outstanding image quality with accelerated scan times
- Ability to deliver a comfortable experience to the patients during the exam with the following hardware and technology
  - Wide bore system
  - Noise minimizing Pianissimo technology
  - MR Theater (immersive Virtual experience)

An Encore upgrade will provide your facility the ability to achieve High Productivity, a Comfortable Patient Experience and Enhanced Clinical Confidence. //

Masato Uchikoshi
Senior Manager,
MRI Systems Division,
Canon Medical Systems Corporation

Masaya Hirano
Global Marketing-Product Manager 3T,
MRI Systems Division,
Canon Medical Systems Corporation

Nami Matsunaga
Global Marketing-Product Manager 1.5T,
MRI Systems Division,
Canon Medical Systems Corporation

Mitsuhiro Uike
Senior Specialist,
MRI Systems Division,
Canon Medical Systems Corporation

With a Little Bit of Help from our Friends, Canon is Taking MRI to New Heights.

Olea Medical

Innovating, pushing the boundaries of medical imaging and preserving life: Olea Medical®, a Canon Medical Systems Corporation company, is a provider of advanced MRI and CT image post-processing solutions. Located near Marseille (France), it designs and markets a range of innovative medical imaging applications, Olea Sphere®, significantly improving the diagnostic process and follow-up evaluation.
Over the years, the company built their strong credibility by gathering internationally recognized experts from leading academic and clinical institutions around the complex problems related to advanced post-processing for the domestication of cutting-edge technology.
By applying calculation time optimization and patented methods based on the Bayesian probabilistic approach to medical imaging, Olea Medical® has become the undisputed reference for advanced, standardized and multi-vendor post-processing, offering accurate and robust qualitative and quantitative analysis. Covering both morphological and functional imaging, Olea Medical®'s post-processing solutions make complex mathematical methods accessible in routine clinical practice, providing easy access to novel biomarkers to improve diagnostic confidence and assessment of treatment response.

Innovation is in Olea Medical®'s DNA and the cornerstone of its vision. With its novel approach of Medical Imaging, Olea Medical® has succeeded in combining complex mathematical models with smart Artificial Intelligence (AI) capabilities within a consistent package of solutions, adopted and trusted all around the world by leading care providers and high-end users.

Positioned as the group's innovation leader, Olea Medical® aims to propel Canon as a key player in MRI by developing fully automatic solutions based on novel algorithms. Through its continuous innovations, its perpetual search for precision, reliability and standardization, Olea Medical® is building the future of medical imaging. With a disruptive approach definitely dedicated to a better user experience, Olea Medical® announce the revolution in post-processing tools, such as the optimization of patient workflow by rethinking the use and design of Canon's future MRI consoles to meet the innovation needs of our customers. //

www.olea-medical.com/en

Fayçal Djeridane, CEO

Olea MEDICAL
Improved diagnosis for life™

Skope Magnetic Resonance Technologies AG
Improving diffusion and MR methods development - showing the way forward:

Skope provides fast, accurate, and robust solutions which accelerate MR methods development and the application of advanced diffusion MRI techniques to fundamental and translational neuroscience.

Imaging is crucial to fundamental and translational neuroscience research. Image encoding errors caused by dynamic perturbations in the magnetic field distort and degrade the image, reducing the value of that image for research. We partner with researchers to achieve the highest quality neuroimages.

Measuring and accounting for dynamic field perturbations using Skope's solutions allows researchers to repeatably acquire images with confidence. For example, diffusion images acquired using Skope solutions no longer exhibit geometric distortions between each encoding direction and more accurately reflect the geometry of the underlying anatomy.

Integrating Skope solutions into your imaging workflow enables advanced acquisition methods which improve SNR. Diffusion imaging with spiral readout modules minimize echo time and have been shown to improve SNR compared to echo-planar readouts. While the reduced echo time improves the SNR of the diffusion acquisition, the acquisition becomes more susceptible to distortion by eddy currents from the diffusion sensitizing gradients. These techniques therefore benefit greatly from concurrent measurement of spatiotemporal field evolution in order to account for the eddy current effects.

NeuroCam™ is an integrated brain coil and field probe array, providing a single point, user-friendly solution to acquire sensitive and accurate measures of neural structure and function as required by the high-end imaging researcher.

skope-i™, the reconstruction software solution for field monitored acquisitions, integrates measured field dynamics into MR image reconstruction. skope-i leverages validated reconstruction algorithms to reliably produce high SNR and geometrically accurate images for MR methods development and neuroscience research.

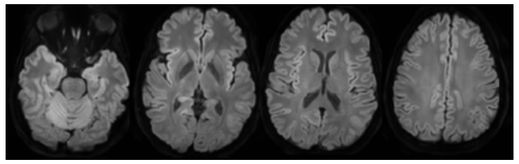


Figure 1: Diffusion weighted images acquired on the Vantage Galan 3T XGO system using the NeuroCam, harnessing the capabilities of field monitoring and advanced image reconstruction using skope-i to improve image quality.

The combination of these **NeuroCam** and **skope-i** create a streamline the workflow which produces robust, repeatable, diffusion data sets to ready for use in neuroscience research or translational trials.

At Skope, we encourage researchers to dream about what they could accomplish with repeatable robust diffusion images in fundamental and translational neuroscience and help them make their leap in imaging performance.

Skope Magnetic Resonance Technologies was founded in 2011 as a spin-off from ETH Zurich and University of Zurich, Switzerland.

True to its name – inspired by the Greek word skopein, 'to observe, to see' – Skope is focusing on bringing accuracy and detail to magnetic resonance imaging (MRI) by combining sensor technology with advanced MR signal processing and image reconstruction. //

Christoph Barmet, PhD CEO

skope

Your Partner in Scientific MR Imaging | www.skope.swiss

Disclaimer:
NeuroCam and skope-i are investigational devices.

VISIONS spoke with Dr. Jean-Christophe Sananes, President of GIE R2 Gironde and Pr. Vincent Dousset, Director of IBIO

French Radiologists Join Forces to Reduce MRI Scan Time with the Vantage Galan 3T

An original alliance using Canon MRI scanners in France has given birth to a new set of sequences to explore the human brain with 3T MRI in just six minutes. This unique collaboration between researchers and clinicians may help tackle MRI access issues in daily practice and could be extended to other clinical applications to improve patient care, two renowned experts told VISIONS.

Left: Dr. Jean-Christophe Sananes
Right: Pr. Vincent Dousset

Apioneering cooperation in France

When the finest clinicians and researchers work together with the same breathtaking equipment, great things can happen.

GIE R2 Gironde, a company that utilizes the expertise of more than 180 radiologists, and IBIO, a prestigious research institute in the Bordeaux region, have known each other for a long time. They have also both recently installed the Vantage Galan 3T MRI scanner. When IBIO researchers started to develop new sequences with the equipment, they opened a new path for the two entities to cooperate more closely, according to GIE R2 Gironde President Dr. Jean-Christophe Sananes.

"In daily clinical routine, we need fast sequences that use AI and denoising techniques," he said. "We were very interested in those sequences that IBIO had been working on."

In late 2020, the organizations decided to join forces to apply the sequences

"One of the main questions is how to develop sequences that can be translated into clinical daily practice. That's why we chose to collaborate with GIE R2 Gironde, whom we've known for a long time, to test the sequences."

Prof. Vincent Dousset, Director of IBIO,
Research institute in the Bordeaux region, France.

developed by IBIO in clinical practice, to help expedite diagnosis and follow-up of patients with MRI. Through the Bordeaux University Foundation, a PhD candidate was hired to help implement this work in daily practice in order to bring optimal benefit to patients.

Canon's Vantage Galan 3T scanner combines some of the most powerful gradients in the world with game changing image improvement techniques such as the Advanced intelligent Clear-IQ Engine (AiCE) software, an AI-based solution that identifies and removes noise from images. With this cutting-edge equipment, IBIO managed to create incredibly fast sequences to boost MRI and spread its use in clinical practice. But these kinds of advances need help to make it into the daily routine setting, IBIO Director Prof. Vincent Dousset explained.

GIE R2 Gironde, Bordeaux, France.

Canon's Vantage Galan at the GIE R2 Gironde.

"One of the main questions that researchers are confronted with is how to develop sequences that can be translated into clinical daily practice," he said. "That's why we chose to collaborate with GIE R2 Gironde, whom we've known for a long time and totally trust, to test the sequences."

Bringing research and clinical practice under one roof is somehow atypical in France, but the approach is starting to pay off. GIE R2 Gironde and IBIO are about to present results that could help shorten and harmonize MRI examinations of patients with brain disease.

"We've developed a large set of very short sequences with high resolution that can be applied to screening most brain diseases as a routine protocol. It's called the Welcome Pack and it enables to expedite and standardize MRI examinations of the whole brain," Prof. Dousset said.

The Welcome Pack[1]: a new tool to help radiologists using MRI

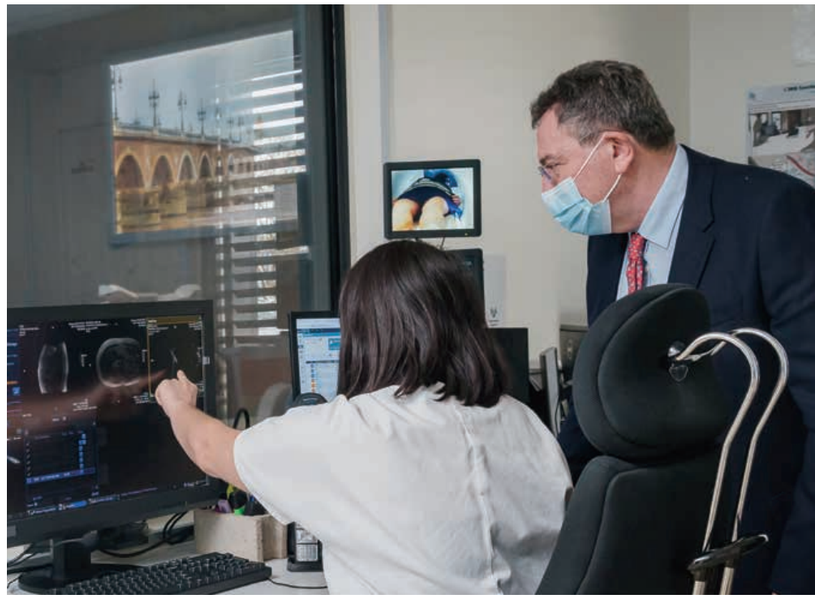
Working in a timely fashion is the radiologist's dilemma when scanning with MRI. "We need to standardize MRI examinations and perform them in a short time, as we do with CT," he said. "We thought of which basic sequences would be necessary to perform MRI exploration of the brain as easily as CT, in order not to miss anything and go fast."

With Canon's help, Prof. Dousset and his team condensed six basic sequences - a T1, T2, FLAIR, TOF, T2* and diffusion - into the same rapid MRI examination to scan all of the brain pathologies.
The goal was to reduce scan time and the team worked on refining every possible sequence technique. "We also drew on other techniques, such as the Fourier transform, and everything we had at hand to optimize sequences. We also applied the AiCE innovative solution available on the Vantage Galan 3T to remove noise from the images."

The outcome is a significant gain in time, offering the ability to scan patients in just five minutes in 2D[1] and six minutes in 3D[2]. Because all the basic sequences have been included in the combination, patients do not have to be scanned again in the case someone else reads the study later.

"The effect is doubled. We can examine patients very rapidly and if there's an additional reading, there's no need to recall patients," Prof. Dousset said.

The experience in daily practice has impressed Dr. Sananes. "We've been using the Welcome Pack on our Vantage Galan 3T for three months and we're extremely surprised and happy to obtain all the information about the brain in just six minutes,"



Dr. Sananes at the GIE R2 Gironde.

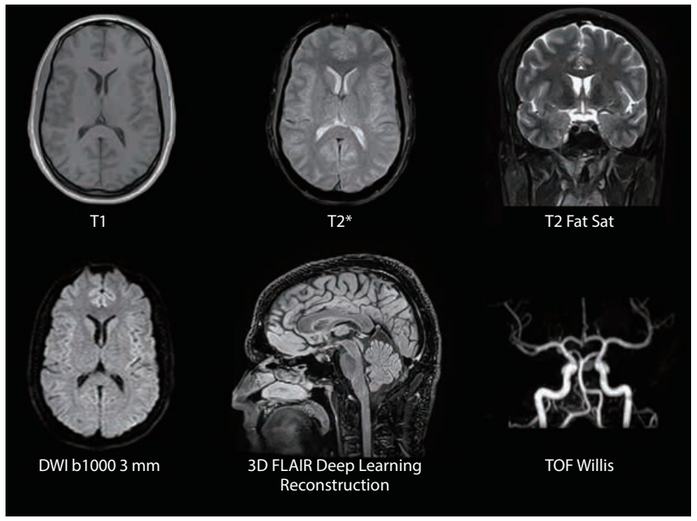


Figure 1: 6 sequences including 3D FLAIR and TOF
Ax T1W : 20 sec, Co T2W FatSat : 33 sec, 3D FLAIR : 100 sec,
*Ax T2*W : 36 sec, 3D TOF : 59 sec, Ax DWI/b1000 : 28 sec*

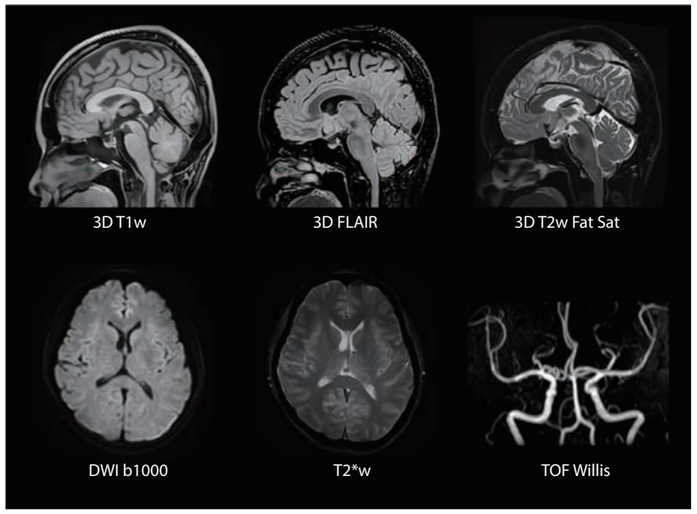


Figure 2: Typical 3D Welcome Pack Images on one volunteer. Total scan time: 6 min 21 sec.
3D T1W: 66 sec, 3D T2W FatSat: 73 sec, 3D FLAIR: 100 sec,
*Ax T2*W: 96 sec, Ax DWI/b1000: 88 sec, 3D TOF: 119 sec*

he said. "We've run tests and use it more and more often. The machine offers very high quality and optimized images. The Welcome Pack brings us a very interesting rapidity without degrading image quality."

Such fast sequences may well enable to design and implement new workflows that shorten MRI waiting times and improve MRI access for both clinicians and patients, Dr. Sananes suggested.

"The solution is very innovative and answers a very strong demand from clinicians who are refrained in their diagnosis by waiting times or the difficulty of obtaining MRI exams. Thanks to those fast sequences, we could unleash MRI's potential to answer clinicians' needs and improve care, notably for semi-urgent patients," he said.

For Prof. Dousset, being able to test his team's research in the clinical setting may pave the way for other interesting projects using fast acquisition and image denoising techniques. "Hopefully we can prove the efficiency of such techniques over already established ones with this project, and look forward to more initiatives in the future," he said.

Potential future applications

Besides brain imaging, a number of applications could benefit from IBIO's fast sequences, including neck and MSK pathologies.

Dr. Sananes would also like to take the Welcome Pack down to the pelvis and the abdomen. "This is a delicate region to image with 3T because of artifacts that are triggered by movement. AI's role is to get rid of those artifacts. Prostate MRI is all set to take off with AI-boosted MRI," he said.

Research is all about pushing the frontiers. MRI already enables the ability to do functional imaging, but advances must be made to improve image quality, Prof. Dousset said. "The prostate, spinal cord and other organs and regions remain complicated to access. There's also a lot of work to be done to image the pituitary gland and vessel wall pathologies, which are quite frequent. Image quality needs to be improved to properly visualize atherosclerosis or aneurysm risk."

With Canon Medical Systems' unmatched support, radiologists have a strong ally to accompany their endeavors.

"The solution is very innovative and answers a very strong demand from clinicians. Thanks to those fast sequences, we could unleash MRI's potential to answer clinicians' needs and improve care, notably for semi-urgent patients."

Dr. Jean-Christophe Sananes, GIE R2 Gironde President

"Our cooperation with Canon Medical Systems scientists has been extremely positive in our collaboration with IBIO. It's rare and brings real advances," Dr. Sananes said.

"We've received excellent technical support from Canon. We have a shared vision of research that enables us to go further and push this idea that transcends the usual French public-private scheme, to develop techniques that improve patient care," Prof. Dousset concluded. //

Patrice Coudray (Canon Medical), Bruno Triare (Canon Medical), Dr. Sananes, Professor Dousset.

References

[1] *Welcome Pack: a standardized brain MR examination with six sequences in less than 5 minutes. Vincent Dousset, M.D., Ph.D. (PU-PH) Director of IBIO University of Bordeaux and University Hospital of Bordeaux; https://global.medical.canon/products/magnetic-resonance/aice-customer-experience*

[2] *3D Welcome Pack with Advanced intelligent Clear-IQ Engine (AiCE): a standardized 3D brain MR examination with 6 sequences in 6minutes. Vincent Dousset, M.D., Ph.D. (PU-PH) Director of IBIO University of Bordeaux and University Hospital of Bordeaux; https://global.medical.canon/products/magnetic-resonance/aice-customer-experience*

Investigating the Wider Impact of COVID-19 Infection

As the COVID-19 pandemic continues to affect everyone, The Johns Hopkins University in Baltimore, Maryland, US, is collaborating with Canon Medical on a ground-breaking study to investigate the wider clinical effects of the disease. The investigation is utilizing some of the most advanced technologies possible to reveal the impact of the disease on the whole body. Dr. Joao Lima, Director of Cardiovascular Imaging and Professor of Medicine at Johns Hopkins University, who is leading the study, spoke to VISIONS about this ground-breaking work.
Amongst others, Dr. Lima is collaborating closely on the study with Dr. Chia Liu, Senior Clinical Scientist at Canon Medical Systems Corporation, who has worked with Dr. Lima in previous years on a significant study into Atherosclerosis (the Multi-Ethnic Study on Atherosclerosis – MESA).

Longer term implications

Investigations into the clinical effects of novel corona virus of 2019 (COVID-19) have begun, because Dr. Lima's team wanted to gather some insight into what happens after the acute disease. This study is a morphological and quantitative analysis of COVID-19 sequalae.

"We have done a lot of studies in patients with acute COVID-19 and we wanted to investigate if patients with the disease would have sequalae in the myocardium, because from our studies in the acute cohort, it's clear that there is a process that involves the heart. We are also particularly interested in measuring fibrosis, and particularly, interstitial fibrosis in the heart, as a way to measure healing from an inflammatory insult. And, of course, not only for the heart, we thought also to image the lungs and the brain. We are in collaboration with our Neuro Radiology Department on this study." remarked Dr. Lima. "In addition, we are acquiring seed data to propose a study to the US National Institutes- plural of Health (NIH) to follow these patients longer term. There are data suggesting that a few months after an insult, the patient can develop a fibrosis in the heart, and we would like to see the consequences of that."

Left: Dr. Joao Lima, Director of Cardiovascular Imaging and Professor of Medicine at Johns Hopkins University
Right: Dr. Chia Liu, Senior Clinical Scientist, Canon Medical Systems Corporation

Specially developed protocol

A protocol for the investigation was designed and developed through the combined expertise of Dr. Lima and his team and Dr. Liu. Some of the techniques are so cutting edge that many are not yet widely used in clinical practice. Along with imaging of the heart, brain, lungs and liver, there are also specific practical challenges posed by the nature of this particular corona virus. Before the public vaccination campaign began in the US, it was not always possible to carry out scans on patients, because of restrictions. In addition, acute COVID-19 patients often have a great deal of pain and other difficulties.

"With COVID-19, it's most important to keep the patient in the scan for the shortest possible time," remarked Dr. Liu. "Our eventual protocol for this study includes T1, T2 mapping on the heart and T1 mapping on the liver, with T2* (ultra-short TE) imaging on the lung. The T2* sequence has such a short TE, less than one millisecond, that we are able to see a lung parenchyma. Diffusion tensor imaging (DTI) is used for brain imaging. We also have lots of parametric mapping techniques that we apply with these patients."

"The images that we've been acquiring by ultra-short TE from the lungs are really remarkable," said Dr. Lima. "We are using the Canon platform for other studies as well, one of which is a pulmonary study. As we are part of a network of nine sites in the United States, we can compare images. Our UTE images are among the best, if not the best."

Basis for a wide range of understanding

The study and its data could provide the basis for further extension, or could provide useful key data for other research groups with an interest in this aspect of COVID-19, such as the longer term clinical effects of different variants of the virus. There is emerging evidence that other conditions, such as Type 2 diabetes, might result from severe or moderate infection cases of COVID-19 [1]. In addition, cases of COVID-19 that are seen in hospitals tend to be due to the severe pulmonary difficulties caused in some people. This may not be the only long term concern about the disease.

"What brings the patient to the hospital is the pulmonary involvement, but we wonder, for example, if a lot of patients that don't come to the hospital actually do have inflammation in the heart, and perhaps in the liver, but we just don't know about it. They could have maybe very little pulmonary involvement, but more cardiac involvement." said Dr. Lima." We want to use the sample seen in the hospital, but also at one point, include people who are symptomatic, but not 'pulmonary enough' to be admitted, and see if there are changes in those as well."

"There is also a syndrome called the 'long haulers'," he continued. "A percentage of people that had the disease appear to be limited afterwards. Those limitations are not yet understood. The patients are generally fatigued and can't perform anymore to the same level they used to perform. We are very interested in this group as well. It is also an important to find out if the disease limits exercise capacity, particularly in people who are top level athletes. In our institution, this relates to our lacrosse team. Several of the lacrosse players at Johns Hopkins have had COVID-19. There is a discussion to begin a study to look at those. And we may be involved at this center - the MRI center."

"The images that we've been acquiring by ultra-short TE from the lungs are really remarkable. Our UTE images are among the best, if not the best."

Dr. Joao Lima
Director of Cardiovascular Imaging and Professor of Medicine
Johns Hopkins University, USA

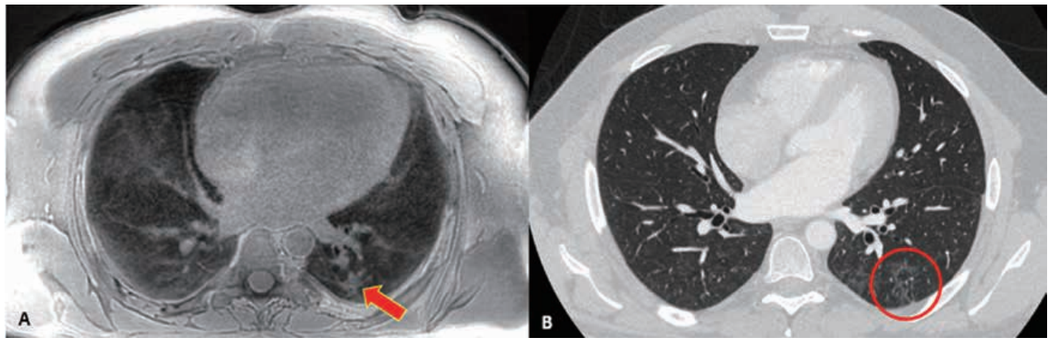


Figure 1: Post hospitalized COVID-19 research participant with ultrashort TE image (A) which demonstrates subtle ground glass opacification and confirmed with CT images (B).

Accessible data

To maximize the 'usefulness' of the study, it is Dr. Lima and Dr. Liu's aim to ensure that the data is as accessible to other research groups as possible.

"We have already had interest from other researchers, for example, Dr. David Bluemke, from the University of Wisconsin, who is studying COVID-19 in athletes and football players. University of Wisconsin is part of the Big 10. Has a very large sports program, and they have over 100 people, for example, in the football team that had COVID-19. Two of them had clear-cut changes, and that's been published[2]. So, David will review particularly our lung images as well, but will be collaborating with us very closely on this. There are other groups that are very interested. Our aim is to publish data, put it out there, and have it as accessible as possible to everyone."

"In addition, the NIH is launching a program to image everybody who has been imaged before in one of their significant studies, including the Multi-Ethnic Study on Atherosclerosis (MESA) and The Coronary Artery Risk Development in Young Adults (CARDIA) study. They call this the cross cohort study, and we're the MRI group for that cross cohort study. So we're going to see participants from other areas of the United States being imaged in the study, so we hope that we're going to have samples from several other parts of the country."

Key collaboration

Canon Medical Systems has a long history of collaboration with Dr. Lima. This began in 2002 at an American Heart Association meeting, when Dr Lima and his team saw images of a CT-guided arterial stent being placed. The team was so impressed that they began to invest in various Canon equipment, which have served the team's research needs very well.

"A few years ago, Canon Medical Systems decided to take space in our biotech park. That was a very important moment, because there was then a decision to site an MR – a Vantage Galan 3T - and we became, therefore, part of the Canon MRI users group. This has been wonderful, and then we had Dr. Liu relocate to work with us, which has been yet another big step in the relationship with Canon Medical Systems."

Acting as a system

The Johns Hopkins Hospital has always been the center of a large network of hospitals in Maryland. Currently, there are five hospitals - two in Washington DC, one midway between Baltimore and DC, and the other two in Baltimore. Johns Hopkins Hospital is well-known as a place where more novel procedures or more challenging therapies happen or are attempted.

"COVID-19 is actually a very good opportunity to demonstrate that we are connected as a system, because we acted as a system," said Dr. Lima. "We tried to bring the more severe patients to the central hospital and now most of the technology is quite distributed, so all the hospitals function at all levels. However, during the first wave of the pandemic, the most severe cases in Baltimore, or even in Maryland, were brought to Johns Hopkins. So we have a lot of records on the most severe cases. We have a very large network of physicians that are affiliated to Johns Hopkins, and so a lot of asymptomatic patients were taken care of outside the hospital, but they were tested in our system and they had information in our IT system, so that we can use that to leverage the ability to study individuals, who were symptomatic, but not admitted. That's what we hope to leverage in the future."

Continuing challenge

While the challenges of the COVID-19 pandemic continue, research with such a strongly collaborative basis is contributing to fighting the world's current health crisis. //

"We have to adopt a global view of the fact that this is a systemic infection, and we must look for possible consequences outside the lungs, and even outside the heart, and be open to chronic sequela that are not/were not obvious at the time of the acute infection,"

Dr. Joao Lima, Director of Cardiovascular Imaging and Professor of Medicine
Johns Hopkins University, USA

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2. *Saurabh Rajpal, Matthew S Tong, James Borchers, Karolina M Zareba, Timothy P Obarski, Orlando P Simonetti, Curt J Daniels. "Cardiovascular Magnetic Resonance Findings in Competitive Athletes Recovering From COVID-19 Infection". JAMA Cardiol. 2021;6(1):116-118.*

Here and Now, Canon's Latest Release Pushes Leading MRI Technology to the Forefront of Clinical Utility

Nami Matsunaga, Global Marketing-Product Manager 1.5T, MRI Systems Division,Canon Medical Systems Corporation
Masaya Hirano, Global Marketing-Product Manager 3T, MRI Systems Division,Canon Medical Systems Corporation

In this article we introduce how Canon's latest MRI releases are transforming the key concepts of Comfort, Confidence and Cost-effectiveness into real world solutions.

1. Changing the game with Advanced intelligent Clear-IQ Engine (AiCE)

In magnetic resonance imaging (MRI), many parameters have an influence on the image. The chosen echo time (TE) and repetition time (TR) are major contributors to the obtained contrast, while the field of view (FOV) and matrix size determine the resolution. All these parameters influence the intensity of the signal. As the amount of signal is proportional to the voxel size, increasing the resolution (thus smaller voxels) is accompanied by a decrease in the signal-to-noise ratio (SNR). This can be compensated by increasing the scan time, which has many drawbacks like decreased throughput, higher chance for motion artifacts and lower patient comfort. Therefore, in MR imaging we are dealing with a trade-off between the SNR, scan time and resolution (Figure 1).

As the SNR increases with field strength, one of the approaches to reduce the inherent tradeoffs is to go to higher fields. However, imaging at higher field strengths comes with other challenges such as increased cost for equipment and operation, but also the allowed RF power deposition is lower which limits the possibilities.

In response to these challenges, Canon has made significant progress to increase SNR on the current magnetic field strengths of 1.5 and 3T by optimizing the system with techniques like PURERF and high-performance amplifiers. In addition to these hardware solutions, Canon has developed an artificial intelligence (AI) based solution to improve SNR. In 2019, Canon introduced Advanced intelligent Clear-IQ Engine (AiCE) to the market on Vantage Orian, making it the world's first Deep Learning Reconstruction (DLR) MRI system approved by regulatory bodies globally. Shortly after the release for Vantage Orian, AiCE became commercially available on Canon's Vantage Galan 3T, Vantage Centurian and Vantage Elan. AiCE utilizes a deep learning reconstruction technique to remove noise from images and restore SNR. The power of deep learning has now been translated into clinical practice to provide exceptional image quality across a wide variety of clinical applications.

Figure 1: (A) Inherent tradeoffs between SNR, resolution, and scan time. (B) Higher field strength can reduce the triangular tradeoff but it is associated with several challenges such as increased equipment and operating cost, increased safety risks due to higher heat deposition to the patient, and increased image artifacts due to higher field inhomogeneities. (C) AiCE is able to alleviate the inherent and fundamental tradeoffs between SNR, scan time, resolution without the challenges associated with higher field strength. Note that the images are not necessarily drawn to scale.

What is AiCE?

AiCE uses a Deep Convolutional Neural Network (DCNN), a class of deep learning networks that excels in image analysis.

The training of a DCNN requires a high volume of training data. The quality of the training data is essential in the success of the algorithm. Therefore, high-quality target images were prepared using motion registration of multiple acquisitions to obtain averaged MR images with ultra-high SNR. These were paired with low SNR images and provided to the network to have it trained on reconstructing exceptionally high-quality images from low SNR images. As clinical images vary in noise level, images containing a range of clinically relevant noise levels were added to the training dataset. This enabled the network to adapt to a range of noise levels and SNR observed in clinical practice.

Next to robustness for various noise levels, AiCE can also deal well with the many variations in MR clinical images caused by differences in scan parameters, sequence design, body region and field strength. To achieve this, an important step in the architecture of AiCE is to separate the high- and low-frequency components in the denoising process. The low-frequency components preserve the contrast of the image and are unaffected, while on the high frequency components denoising is performed. This makes AiCE robust to contrast variations from different parameters, field strengths and clinical protocols. (Figure 2).

The reconstructed images are comparable to images acquired with a high number of averages, without the burden of long scan times or intense pre-processing that are required in routine clinical workflow. AiCE's training is computationally intensive; however, the training was performed offline before the model is deployed on a clinical system. During operation in clinical use, the AiCE reconstruction is generally fast because there is only a single feed-forward computation.

AiCE in clinical use

As stated above, in MRI there is always a tradeoff between scan time, SNR and resolution. AiCE relaxes these constraints and provides the user with much more flexibility. Here, we will demonstrate the benefits of using AiCE in clinical use.

Extended scan time has several issues. In particular, it has some challenges to scan images without motion artifact in motion sensitive regions. The cervical spine shown in Figure 3 is one example. The operator may ask the patient to be stable during the examination however it is often difficult to keep still for the entire examination. In addition, it could be affected by cerebrospinal fluid (CSF) flow. As a result, images often suffer from the artifacts shown in the left-hand side images. Applying AiCE can improve this situation because AiCE can help to reduce scan time with-

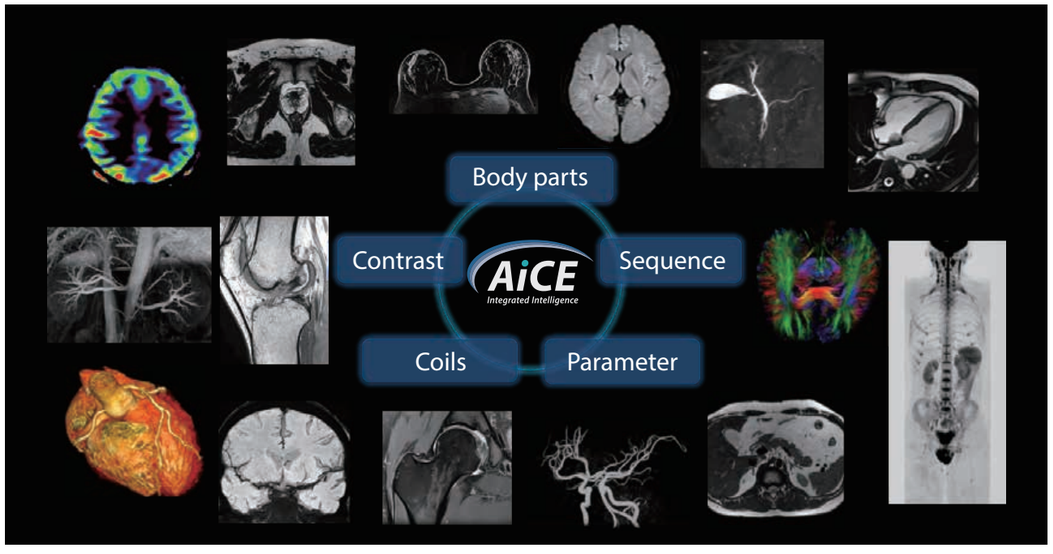


Figure 2: AiCE covers up to 96% of MR procedures[1]

out compromising SNR. As shown in the right-hand side images in Figure 3, reducing scan time can reduce motion artifacts and flow artifacts as well as reduce the pressure on the patient. AiCE helps both the operator and the patient with a successful and comfortable examination.

AiCE can be combined with all of Canon's acceleration techniques, making AiCE very versatile in speeding up exams. Typical acceleration methods are lowering the number of averages or increasing parallel imaging factors, but both methods affect the SNR. However, now AiCE can be used to restore the SNR. Canon has two techniques for parallel imaging: SPEEDER and Exsper. In parallel imaging, the SNR is reduced by the square root of the acceleration factor, but the noise is also dependent on the coil geometry and sensitivity maps. This is well known as the geometry factor (g-factor). Due to the g-factor, the noise might not be homogenously distributed over the image. The latest version of AiCE has been updated with a noise estimate that takes the g-factor noise into account to obtain a homogenously denoised image (Figure 4). Utilizing this method, AiCE enables high acceleration factors and faster scan times while maintaining image quality.

In addition other acceleration techniques like Compressed SPEEDER, Fast 3D and Water Fat Separation (WFS) benefit from AiCE. Compressed SPEEDER is Canon's unique implementation of compressed sensing. Compressed SPEEDER enables scan acceleration both in 2D and 3D and is applicable in various body regions and RF coils. As scan acceleration

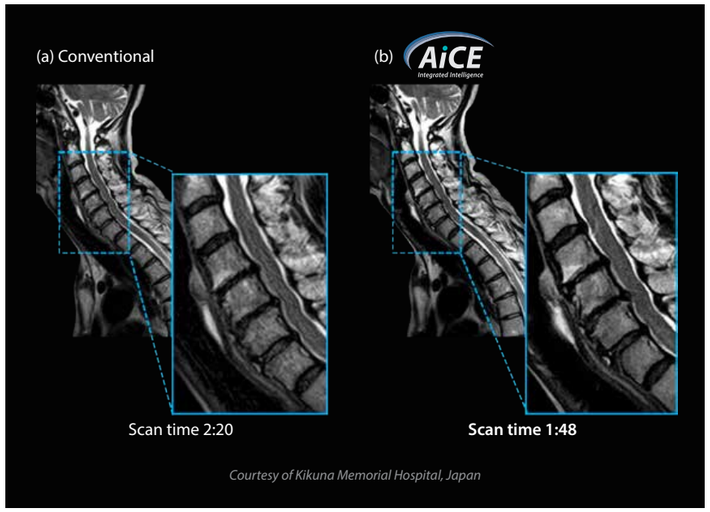


Figure 3: Stable fat suppression to mitigate the risk of mis-diagnosis
(a) Conventional:
T2w, 0.8×0.8 mm resolution, 3.0 mm, 2:20
(b) AiCE:
T2w, 0.6×0.6 mm resolution, 3.0 mm, 1:48

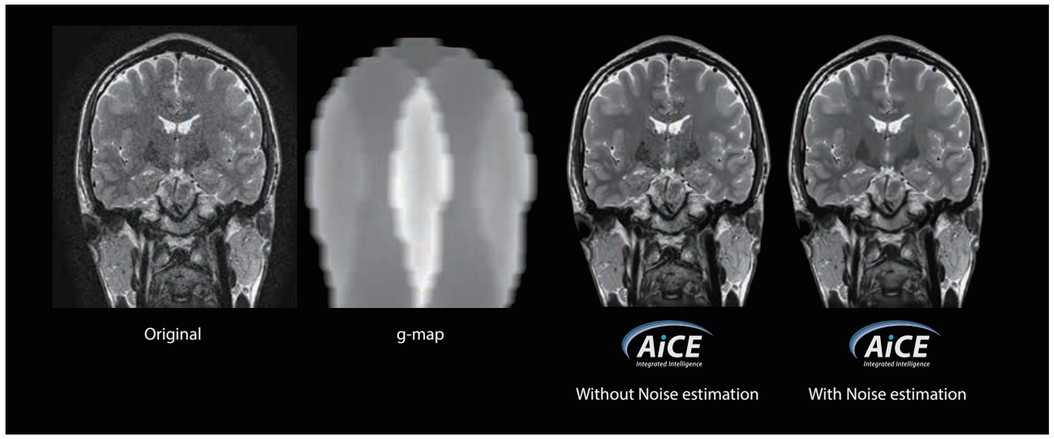


Figure 4: The latest version of AiCE estimates noise based on g-factor for homogenous denoising over the whole image.

usually comes with a decrease in SNR, Compressed SPEEDER combines well with AiCE to maintain image quality.

As seen in Figure 5, this combination of Compressed SPEEDER and AiCE can reduce the total examination time by more than half, which contributes to workflow improvement, cost performance due to better throughput and patient comfort in the bore.

Next to accelerating 3D acquisitions by Compressed SPEEDER, we have expanded our Fast 3D technology to 3D Time of Flight (3D-TOF) and 3D Steady State Free Precession (3D-SSFP) acquisitions. Fast 3D uses an intelligent k-space sampling scheme that facilitates acceleration of 3D scans by up to 50%[2]. Like with our other acceleration techniques, Fast 3D also can be combined with AiCE to restore any loss in SNR. Since its introduction, many customers are successfully using AiCE in combination with our accelerated scan technologies in routine clinical practice.

WFS is a Dixon technique to obtain simultaneous and in-phase (regular contrast) and water-only image (fat saturation) of the same contrast weighting. It is often the case that WFS is used on challenging regions for homogenous fat suppression like the hand, foot or neck. WFS is ideal for fat sat imaging, but also sufficient SNR is required for such regions. Therefore, AiCE is now well accepted for this application as shown in Figure 6.

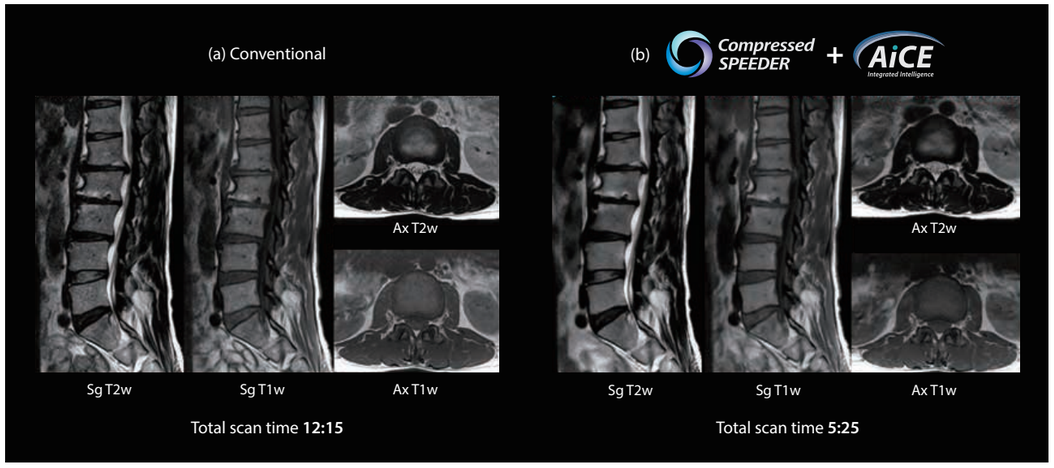


Figure 5: Combination of Compressed SPEEDER and AiCE can reduce the total examination time by more than half
(a) Sg T2w 3:10/ Sg T1w 2:53/ Ax T2w 3:28/ Ax T1w 2:44 (b) Sg T2w 1:06/ Sg T1w 1:28/ Ax T2w 1:27/ Ax T1w 1:24

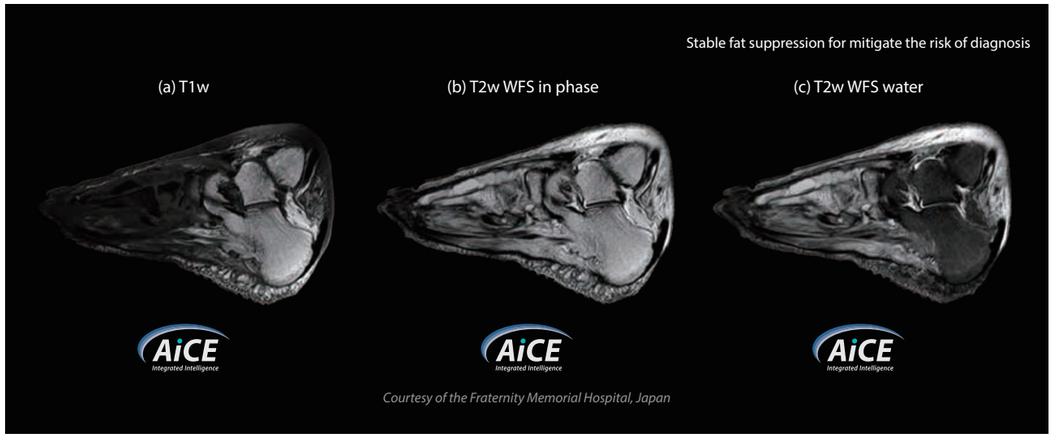


Figure 6: Stable fat suppression to mitigate the risk of mis-diagnosis. Suspected osteomyelitis, possible abscess formation
(a) 0.6 x 0.6 mm resolution, CS x 1.5, 3.0 mm, 1:15 (b) 0.7 x 0.6 mm resolution, 3.0 mm, 2:48 (c) 0.7 x 0.6 mm resolution, 3.0 mm, 2:48

Versatility of AiCE
Since AiCE is not dependent on anatomy, contrast, sequence, coils or parameters, it provides full flexibility in using AiCE to respond to any given clinical situation (Figure 2). As AiCE removes only Gaussian noise, the usability expands beyond the more standard sequences like Fast Spin Echo (FSE) or Fast Gradient/Field Echo (FFE) and can be applied to techniques like MR angiography, diffusion-weighted imaging (DWI) or WFS to name a few. Moreover, since AiCE only removes Gaussian noise, it can be used for quantitative imaging as well (Figure 7).

Figure 7 demonstrates that AiCE does not affect the quantitative values in DWI. To accelerate the acquisition of DWI, in the latest software release Exsper comes as a standard feature. Exsper is an advanced parallel imaging technique for DWI, which can reduce distortion. In combination with AiCE, acceleration factors that were not clinically feasible before are now possible (Figure 8).

To summarize, AiCE alleviates the constraints between SNR, scan time and resolution, opening possibilities to scan at higher resolution or shorter scan times or a combination of all three. As AiCE is independent of anatomy, contrast or coils it is applicable to almost all examinations, increasing the flexibility of MR imaging for all clinical segments.

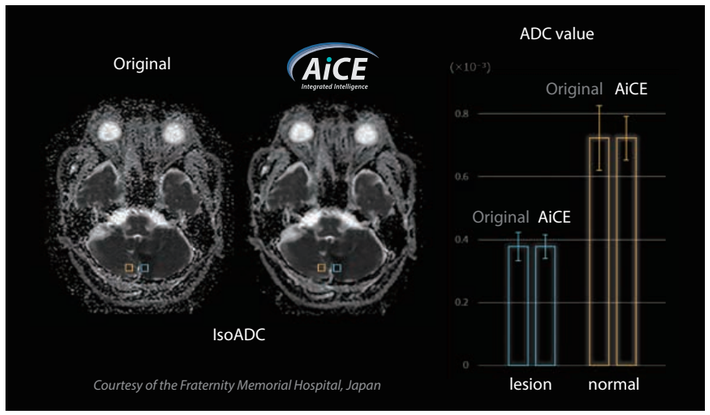


Figure 7: ADC mapping of cerebral infarction.

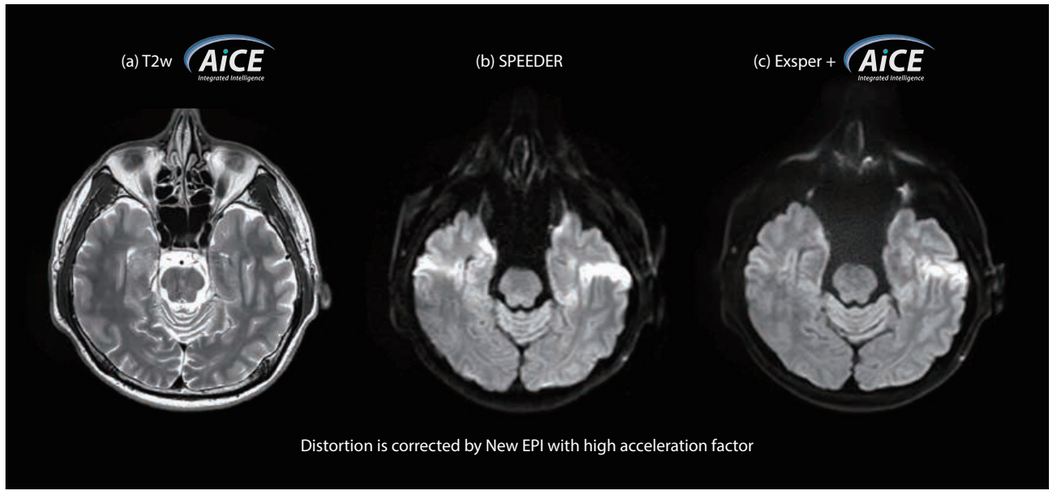


Figure 8: Comparison between DWI image with SPEEDER and Exsper+AiCE. Exsper helps to correct distortion with higher acceleration factors
(a) T2w + AiCE (b) SPEEDER x2 (c) Exsper x 6 + AiCE

2. Delivering more intelligence and accuracy where it is needed

In conjunction with our AI technology presented above, our latest systems incorporate a suite of other intelligent technologies to support accurate diagnosis and simplify scan planning.

Fat Fraction Quantification
The role of fat quantification in the liver in the diagnosis of non-alcoholic steatohepatitis (NASH) and non-alcoholic fatty liver disease (NAFLD) has been important. Fat Fraction Quantification, which is released as a new application in V7, is a multi-echo FE3D sequence and from the acquisition the following data are generated: PDFF (Proton Density Fat Fraction), R2*, water, fat, in-phase and out of-phase images. Acquisition is fast: whole-liver coverage is attained in a single breath-hold (Figure 9).

Ultra-short TE (UTE), Multi-echo UTE
UTE is a unique application that utilizes 3D radial sampling from the center of k-space outwards using spherical trajectory. The advantage of this application is that data can be acquired with ultra-short TEs of less than 100 microseconds. This enables imaging in the pulmonary region which is difficult with longer TEs due to the strong susceptibility effects or in tissues with very short T2* tissues, like cartilage. UTE is also available with Time-SLIP, Canon's unique non-contrast technique which enhances clinical confidence. (Figure 10) Multi-echo UTE collects and processes multiple echoes in one scan and from this, a T2* map can be produced for quantitative assessment.

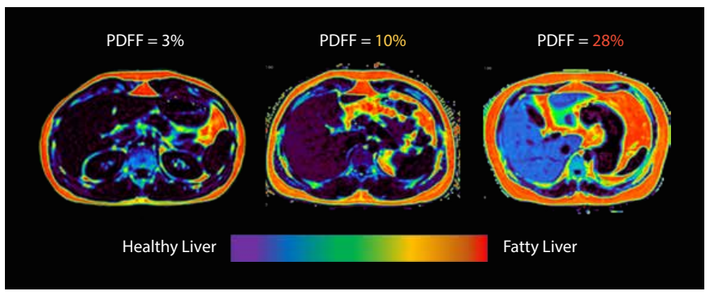


Figure 9: Proton Density Fat Fraction (PDFF) of three different persons calculated by Fat Fraction Quantification application

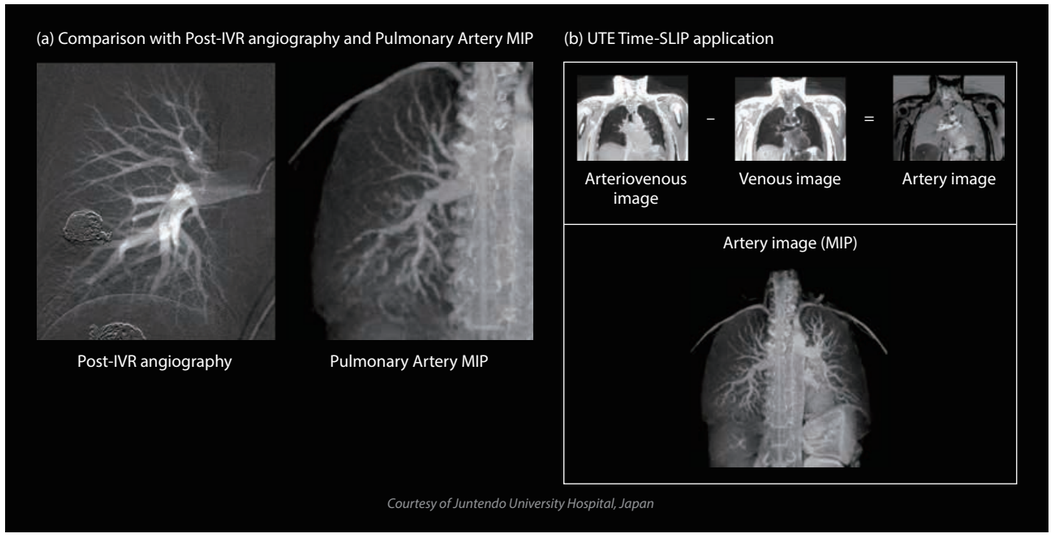


Figure 10: Clinical benefit of UTE. UTE combined with Time-SLIP enhances the ability to visualize the pulmonary artery.
(a) Comparison with Post-IVR angiography and Pulmonary Artery MIP for Follow-up after coil embolization of Pulmonary arteriovenous fistula
(b) UTE Time-SLIP application. Pulmonary artery image utilizes subtraction of the venous image from the Arteriovenous image

ForeSee View

ForeSee View is a unique scan planning tool designed by Canon that displays in real-time the predicted images from existing images. These real-time multiplanar reconstructions show the operator during planning process how the slices will be acquired and therefore greatly simplifies slice planning. This tool is particularly useful in anatomies that can be difficult to plan such as the pancreas, the heart, and certain orthopedic joints, reducing the need for re-scanning and saving time on scan planning for all body regions. (Figure 11) //

Figure 11: Scan planning with the ForeSee View application

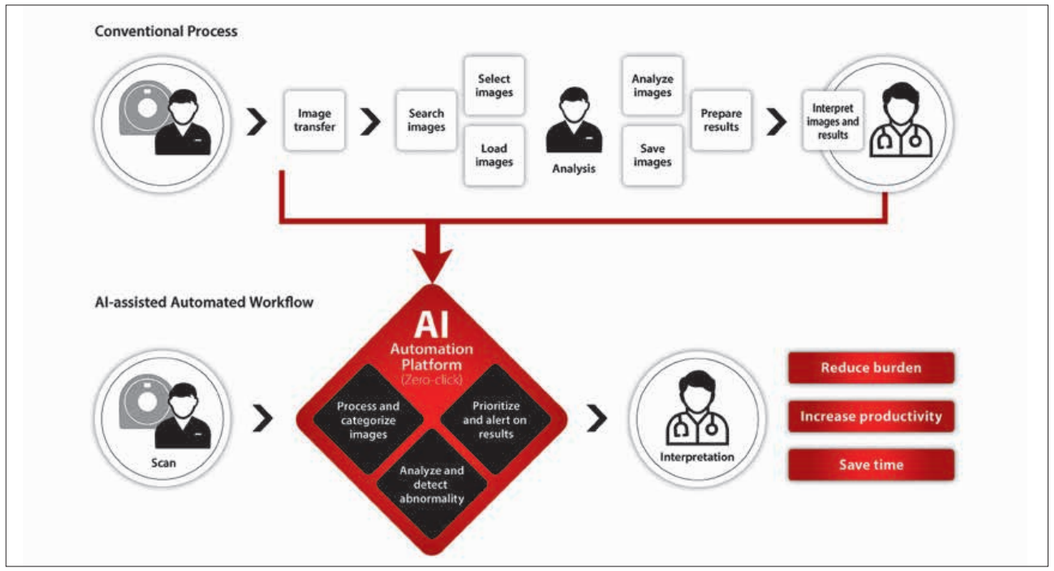
[1] *Based on the IMV report on total MR Procedure Volume in 2019*
[2] *As compared to standard sequence.*

Canon Deep Learning Integrated Intelligence Solutions

Dr R Shrestha

Introduction – Automation Platform

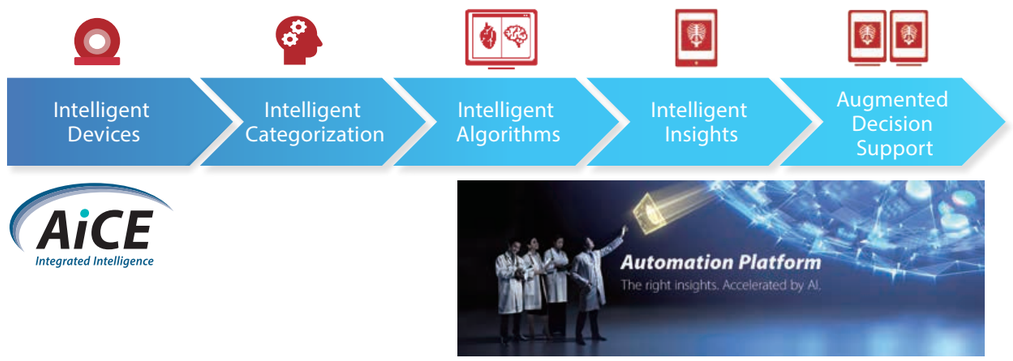
Canon's Automation Platform is an AI-based, zero-click solution that uses deep learning technology to streamline your workflow for fast, actionable results every time.



Automation Platform: Deep learning, automated clinical workflow for data extraction, data sharing and optimized patient info management.

AI workflow optimization

Canon's Automation Platform brings additional layers of intelligence to our Collaborative imaging offering and completes the customer workflow to deliver integrated intelligence from acquisition to analytics.



"After the CT scan, all the rest is automated. This clearly reduces technicians' workload. (Automation Platform) enables physicians to anticipate how long it may take to complete the process from scanning to image analysis, alleviating wait-time stress for physicians. I expect a lot from Automation Platform in terms of improved workflow, particularly in the beginning stages of treatment for acute stroke patients who need fast and accurate diagnosis and treatment decisions."

Dr. Hiroyuki Kawano, MD, PhD
Kyorin University School of Medicine Hospital,Tokyo, Japan

Canon's Automation Platform maximises the power of deep-learning AI, and the integrated intelligence of CT/MR Adaptive Intelligent Clear IQ Engine (AiCE), to automatically perform the following tasks, and reduce your workload:

- **Collect & Curate:**
  - Automatically collect and process clinically relevant patient data including optimised image reconstruction during acquisition using deep learning based Adaptive Intelligent Clear IQ Engine (AiCE)
- **Process and categorize:**
  - Intelligently and accurately classify incoming DICOM data using pixel data analysis, and auto dispatch to relevant applications based on intelligent rules.
- **Evaluate images and help to detect abnormalities:**
  - Clinical applications that use AI to run fully automatically and produce standard results for your interpretation
- **Deliver results & alerts**
  - Streamline clinical workflow with concise summary of the right results, with alerts to potentially urgent conditions; thereby augmenting clinical decisions.

AP: Future-proof DLR platform for multiple care continuum

Canon's Automation Platform has been designed on a brand-new technical architecture that uses the latest deep learning innovations to improve deployment, scalability, installation and maintenance.

Robust clinical testing has shown that Automation Platform DL technology delivers clinical accuracy and reproducibility during image processing and catagorisation.[1]

AP is the future-proof platform designed to deliver total end-to-end workflow for multiple care continuums, starting with stroke. From scanner to clinical decision, you'll be supported by leading-edge deep learning technologies that process and deliver images for accurate triage, worklist prioritization and treatment decision.

Instead of adding a platform on top of a large portfolio of legacy applications, we started by first designing a state-of-the art platform based on the latest technologies. Now we can introduce the best possible clinical applications with seamless, highly configurable workflows on top of a robust intelligent AI platform.

Canon's AUTOStroke solution

Time is Brain

- When it comes to optimizing treatment outcomes for stroke patients, speed and accuracy are everything. Timely screening and triage of Stroke patients is essential to expand the treatment window and provide the right life-saving treatment; especially in growing number of primary & comprehensive stroke centers globally.
- Current imaging techniques that can identify Stroke are widely available in emergency departments, but their use is limited by the need for specialized neuroradiologists to interpret the images
- AUTOStroke can automate time-critical stroke and post trauma workflow using an innovative AI-driven platform & deliver time-critical insights for patient decisions

The AUTOStroke insights

- AUTOStroke solution integrates a comprehensive set of applications to help you quickly categorize and treat ischemic and hemorrhagic strokes including:
  - Non-contrast CT Intracranial Hemorrhage
  - CT Large Vessel Occlusion
  - CT Brain Perfusion including Bayesian CTP+ algorithms
  - ASPECTS*

** Not available in all geographies.*

The patient-specific findings from the above applications are consolidated into a personalised Insights Results, which can be distributed to the emergency department and the stroke care team.

The clinical insights, integrated within smart clinical workflow, alerts the abnormalities and allows the stroke care teams to undertake accurate diagnosis, triage and treatment decisions within minutes.

The Stroke solution has been thoroughly validated through clinical trials and studies and has been proven to:

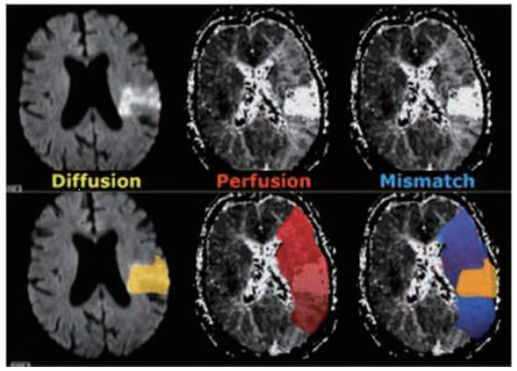
- Deliver speed, accuracy and clinical confidence to emergency and stroke teams to aid in clinical evaluation and treatment.
- Reduce variability between reporting clinicians with accurate, reproducible results.

AUTOStroke solution for MR (W.I.P)

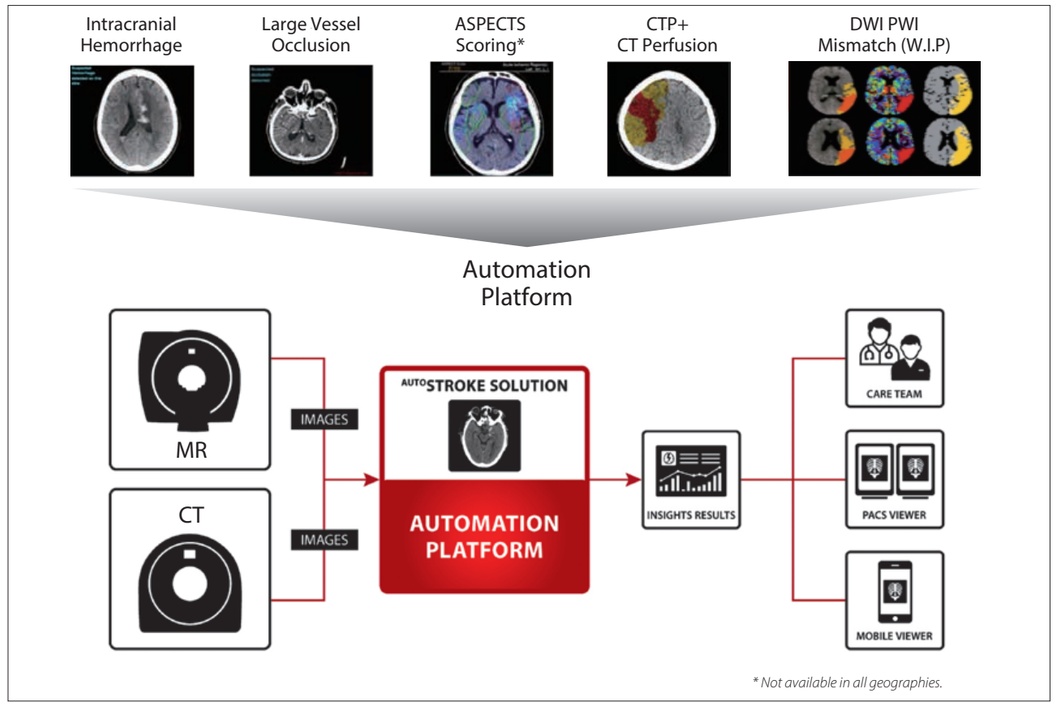
If available, MRI or MRA with diffusion-weighted imaging (DWI) is the preferred imaging modality for patients with transient ischemic attack (TIA) due to increased sensitivity for detection of acute ischemic brain lesions.[2]

MR DWI has emerged as the most sensitive (88% to 100%) and specific (95% to 100%) imaging technique for acute infarct, far better than NCCT or any other MR sequence. And the combination of DWI and PWI before intravenous tissue-type plasminogen activator confirms the diagnosis in 97.5% of all ischemic strokes.[3]

According to the guideline from the American Academy of Neurology, doctors should use a diffusion MRI scan to diagnose stroke instead of a CT scan – with MRI having improved accuracy for lesion detection and stroke severity.



Diffusion image indicates an area with irreversible infarction (yellow). Perfusion image indicates a large area with hypoperfusion (red). Mismatch indicated in blue is the penumbra.



** Not available in all geographies.*

"...having the Automation Platform lets me be able to interact with the data and make a read within minutes allows me to make a decision much faster than the 15, 20-minute turnaround for some of these automated platforms."

Dr Kenneth Snyder, MD, PhD, FACS, FAANS
Associate Professor of Neurosurgery,
SUNY, Gates Vascular Institute, Buffalo, NY, USA.

"In multiple internal and external benchmarks, we have seen that the performance of hemorrhage detection exceeding 95% accuracy and a higher than 97% accuracy in vessel occlusion. These are benchmarks that we are very comfortable in and helps the clinician gain trust, ensuring that the AI solution is a tool that they can work with a reliable and robust way."

Dr Peter Chang, MD
Co-Director, Center for AI in Diagnostic Medicine,
Assistant Professor-in-Residence, Radiological Sciences, School of Medicine, UC Irvine, CA, USA.

Diffusion MRI should be considered more useful than a CT scan for diagnosing acute ischemic stroke within 12 hours of a person's first stroke symptom.[4]

The future-proof Automation Platform – designed to include multiple care continuum and smart algorithms – is being expanded to include MRI DWI/PWI and mismatch as additional stroke care workflow tools for AUTOStroke.

The Automation Platform with AUTOStroke provides a new software paradigm / technique are emerging that can automatically analyze the images and characterize the stroke without the need for a specialized neuroradiologist; and provide instant access to the emergency department and the stroke team to make better triage and treatment decisions

From scanner to clinical decision, you will be supported by leading-edge intelligent technologies that process and categorize images for accurate triage – fast and intelligently.

Key Clinical benefits - AI-Automation Platform & AUTOStroke solutions

1. Harness the power of deep learning

- The deep learning based, Automation Platform, together with Canon's leading-edge DLR scanners provide a complete, automated and streamlined workflow solution from acquisition to clinical decision to intervention.

2. Make the right treatment plan for your patients

- Within minutes, the comprehensive AI-driven AUTOStroke solution, provides an integrated personalised Insights Results – including help to detect signs of ischemic and hemorrhagic stroke

3. Stroke triage that's fast and intelligent

- Where Time is Brain, AUTOStroke helps to automatically characterises any type of stroke; speeds up time to decision and expands the treatment window and help provide the right life-saving treatment decision and clinical intervention.

4. Insights results to make critical clinical decisions

- AUTOStroke is expected to increase clinical confidence and improve patient outcomes by providing the right clinical insights for optimal triage and uniform clinical management. //

Ravi Shrestha, PhD DIC ACGI
Senior Director,- Global Healthcare IT Division, Canon Medical Systems Corporation

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4 *Provost C, Soudant M, Legrand L et.al., Stroke - Volume 50, Issue 3, March 2019, Pages 659-664; "Magnetic Resonance Imaging or Computed Tomography Before Treatment in Acute Ischemic StrokeEffect on Workflow and Functional Outcome".*

Plan for Success with Canon's Unique ForeSee View

Shingo Kodaira, Mark W. Golden

ForeSee View is one of Canon's original applications. Depending on the country or region, it usually comes standard on the latest Canon MRI systems.
By utilizing this unique application, operators can preview the Multiplanar reconstruction (MPR) image in real time according to the planning operation, and accurately find cross-sectional views of all regions with complicated anatomy, such as orthopedic joints, the heart, or the carotid artery.
Traditionally, if a scan region is detected inaccurately an operator is required to take additional scans, extending the length of the examination. And when examinations run over, it has a cumulative effect on the overall running schedule for the day, impacting on waiting patients and causing overtime for staff. So what are the common cases where a false cross-sectional view may occur? A common example is the Anterior cruciate ligament (ACL) which is difficult for operators to plan for because the orientation differs according to the individual. Conventionally, operators had to make fine adjustments to the angle that allowed the ACL to be viewed clearly, forcing the need to re-take the scan when they have difficulty in detecting the desired cross section. In addition to some orthopedic joints, cardiac MRI is thought to be the most difficult examination due to complicated cardiac anatomy. Our MRIs make it easier to plan for normal heart or even cardiac heterotaxia automatically utilizing our scan assisting applications, "CardioLine+" and "SUREVOI Cardiac", however even those unique tools have difficulty in detecting the scan region for cardiac congenital malformations.
However, by utilizing ForeSee View in those difficult cases, operators can preview in real time the cross-sectional view that they are going to see allowing them to reliably set the scan planes as they need.
As shown in Fig. 1, the MPR image is created based on the acquired position / angle information from the imaging ROI, and displayed on the ForeSee View window, allowing operators to check the slice detection in real time in the planning stage. Moreover, operators can use this application for all body regions regardless of RF coils or pulse sequences. On a daily basis, this highly productive technology reduces the need for re-scanning, and consequently contributes to the reduction in total examination times.

ForeSee View was first released in 2018, and subsequently updated on our version 7 software update released at the end of 2020. The following items were added as new features:

- Preview each slice position by using the position slide bar on the window or the scroll wheel of the mouse
- Make it easier to check the slice position by clicking each TOP/MIDDLE/BOTTOM button
- Make it easier to update slice thickness of the MPR image in real-time in the ForeSee View window

Figure 1: ForeSee View setting screen
Operators can intuitively obtain the desired slice section in real time. ForeSee View is useful for slice detection that requires double oblique.

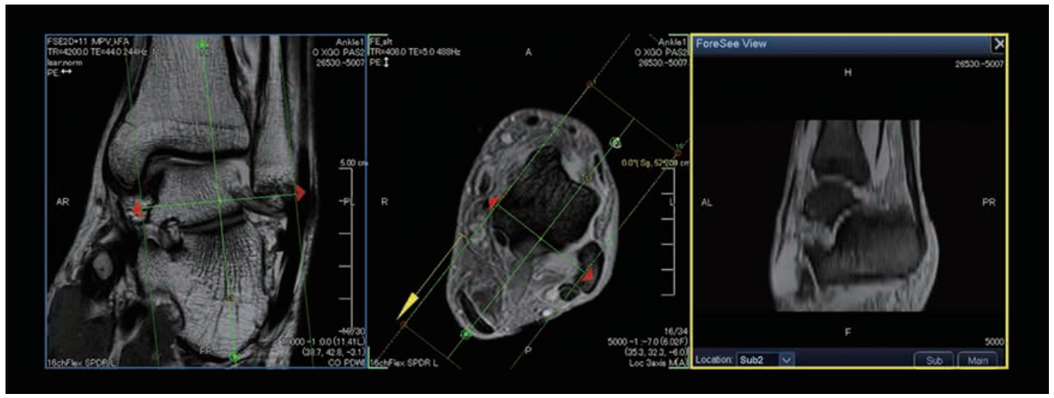


Figure 2: Case of Achilles tendon on the V6 system
The right yellow frame shows ForeSee View window. Operators can check the slice angle and range on this window beforehand. In this case, the ForeSee View window displays a pre-scanned T2 star image.

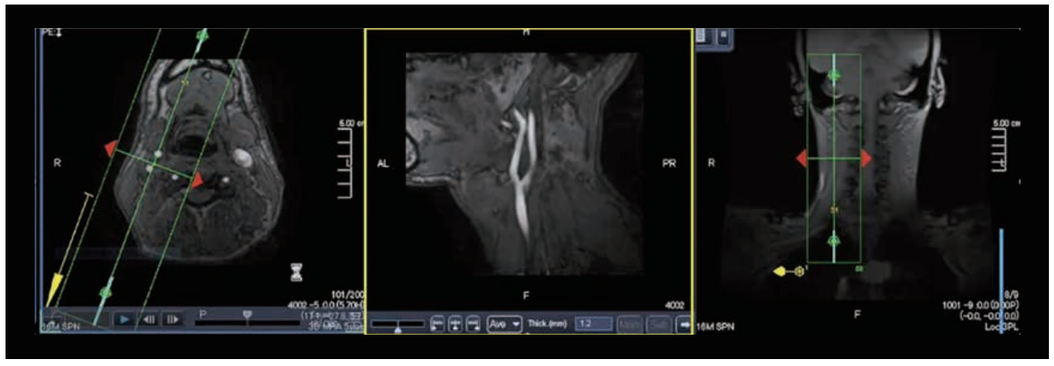


Figure 3: Case of carotid plaque image on the V7 system
The center yellow frame shows ForeSee View window. A pre-scanned TOF-MRA image is on this window. Operators can use even the MIP image to check the slice angle and range on the ForeSee View window.

- Make it easier to switch the location of ForeSee View window
- Select and preview the reconstruction image such as Average Intensity Projection (AIP), Maximum Intensity Projection (MIP), or Minimum Intensity Projection (mIP).

In the past, operators have been able to select the slice orientation or the slice position to obtain long-axis images easily and intuitively by utilizing ForeSee View during routine examinations. The new features noted above will further improve the operational workflow. Operators can use MIP images of TOF-MRA as the planning image, and check the slice orientation or range on the enhanced ForeSee View window. For example, the case of Achilles tendon on a V6 system and carotid plaque imaging on a V7 system are demonstrated in Fig.2 and Fig.3, respectively. Utilizing this method, operators are now able to experience the benefits of ForeSee View for a wider range of examinations. ForeSee View, Canon's original application, was introduced in this article. Canon would like to deliver equipment that is not only patient-friendly but also easier to use for MRI operators. //

*Left:***Shingo Kodaira**
Deputy Manager, Marketing & Promotion, MRI Systems Division
Canon Medical Systems Corporation

*Right:***Mark W. Golden (BSRT)**
Director of Strategic Global MR Clinical Applications
Canon Medical Systems Corporation

New Vantage Elan / NX Edition

Canon Medical has successfully launched its latest 1.5T MR - the Vantage Elan / NX Edition. The new system completes Canon's intelligent and productive MR Portfolio. Two diagnostic imaging facilities in Europe, one in Germany and another in Italy, are the first to benefit from its advanced technology.

Advanced functionality

The new functionalities of the Vantage Elan / NX Edition are designed around customer and patient benefits. Meeting demand for high-resolution images with no compromise and faster scan time remains the top priority for all radiologists. With Advanced intelligent Clear-IQ Engine (AiCE) and Compressed SPEEDER, the Vantage Elan / NX Edition can provide this. AiCE can be used in 96%* of the system's MRI applications. It reduces scan times and simultaneously improves image quality. Fast 3D - a technique to accelerate 3D studies by up to 50% has been extended to cover 'Time of Flight' studies, and is also available with the Vantage Elan / NX Edition.

"The implementation of AiCE has significantly accelerated our Canon Vantage Elan. The number of patients examined per day has increased, while the image quality remains good with a reduced scan time."

Prof. Reinhard Tomczak, Head of Center, Zentrum für Radiologie Bad Friedrichshall (Bad Friedrichshall Radiology Center), Germany.

Ease-of-use and streamlined workflow are also always fundamental requirements for MR users. The Vantage Elan / NX Edition features software that provides new technological possibilities through multiple functionalities, such as ForeSee View, KneeLine+, SpineLine+ and more. These advanced techniques ensure reproducible image quality, automate the planning process, and avoid the need to re-plan and re-scan in challenging studies, including cardiac- and ankle-imaging.

Superior results

The Center for Radiology and Nuclear Medicine, in Bad Friedrichshall, Germany is a multi-center radiology clinic

* *Based on the IMV report on total MR Procedure Volume in 2019*

"With AiCE we can reduce the scan time while keeping high standards in terms of image quality, and improving patient compliance."

Dr. Paolo Bernasconi, Radiologist, Studio Radiologico Bernasconi (Bernasconi Radiology Clinic), Seregno, Italy.

headed by Professor Reinhard Tomczak with a team of more than ten radiologists. The center has acquired a Vantage Elan / NX Edition to achieve precise and quick MR imaging for a wide spectrum of applications, including Cardiac MR.

The Studio Radiologico Bernasconi is a well-known diagnostic imaging center in Seregno, Italy. The center receives patients with various conditions and imaging needs from the public national healthcare system of the Lombardy region. The center is headed by Dr. Paulo Berasconi and has a team that includes six multi-specialized radiologists. The center is already renowned for its excellence. Outstanding image quality is essential in meeting its objective to achieve the highest diagnostic confidence possible. With the Vantage Elan / NX Edition, the center has been able to improve image resolution across different anatomies, including brain, liver, shoulder and knee, with significant and measurable improvement in Signal to Noise Ratio (SNR). In addition, the scan time for some challenging applications, like prostate MR, has been reduced by 36%.

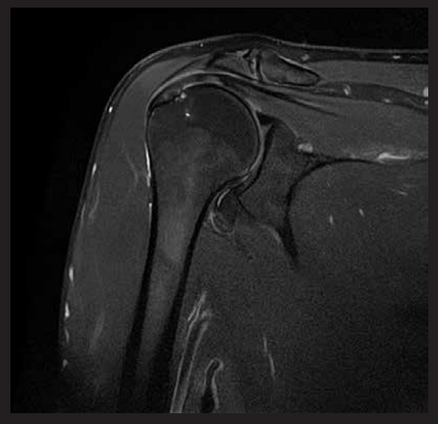
Intelligent MR: Fast, Efficient and Compact

Fast, efficient and compact, the Vantage Elan / NX Edition is a next generation MRI that offers a broad spectrum of benefits. //

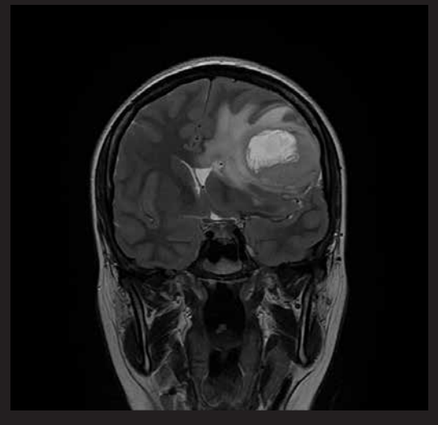
"With AiCE we have better tissue contrast and it is easier to identify the margins of the lesions."

Dr. Francesca Invernizzi, Radiologist, Studio Radiologico Bernasconi (Bernasconi Radiology Clinic), Seregno, Italy.

Ankle sagittal T2 (0.2 × 0.2 mm resolution, 3 mm slice).



Shoulder coronal T2 FS (0.3 × 0.3 mm resolution, 3 mm slice).



Brain coronal T2 (0.3 × 0.3 mm resolution, 4 mm slice).

Courtesy of Studio Radiologico Bernasconi (Bernasconi Radiology Clinic), Seregno, Italy.

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Next-Generation Clinical Images Acquired Using ZGO in the Field of Orthopedics

Takahide Kakigi, M.D., Ph.D.

Vantage Galan 3T / ZGO*, a next-generation high-resolution 3T MRI system manufactured by Canon Medical Systems, has been in operation at our hospital since August 2019. In this lecture, to illustrate some of the applications of the ZGO system in the field of orthopedics, I would like to discuss the clinical usefulness and future potential of Deep Learning Reconstruction (DLR), a noise reduction reconstruction technology employing AI that is available as a product called Advanced intelligent Clear-IQ Engine (AiCE), Compressed SPEEDER, a compressed sensing (CS) technology, and ultrashort TE (UTE) Multi Echo, an ultrashort echo time technology.

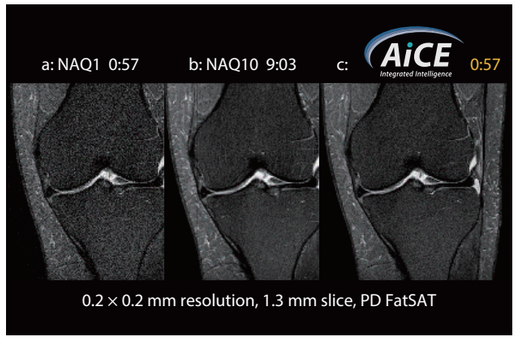
High-resolution imaging with DLR

In the field of orthopedics, it can be difficult to detect or evaluate lesions such as rotator cuff tears or labral tears using conventional MRI due to its limited resolution. In addition, high-resolution imaging is necessary to obtain a clear understanding of the extent of injury and the precise location of lesions. Although high-resolution images with a high signal-to-noise ratio (SNR) can be obtained by increasing the resolution and the number of imaging acquisition (NAQ), this results in a long scan time. High-resolution images can also be obtained using a surface coil, but the FOV is restricted in this case. It would therefore be ideal to have the ability to scan a wider range with a level of resolution equivalent to or higher than that of a surface coil.

AiCE is a noise reduction reconstruction technology that is based on the deep learning method. This method involves training a neural network to computationally generate images that are as close as possible to high-quality training images from input images that contain a significant amount of noise, resulting in the creation of a deep convolutional neural network (DCNN). By installing the DCNN in a diagnostic imaging system, low-SNR images acquired by the system can be denoised and converted to high-SNR images. Compared to a low-SNR image acquired with NAQ1 (Figure 1a), the SNR is improved in an image acquired with NAQ10 (Figure 1b), but the scan time is significantly longer. However, when AiCE is applied to an image acquired with NAQ1, an SNR equivalent to that of an image acquired with NAQ10 can be obtained with no increase in the scan time (Figure 1c).

When a standard smoothing filter is used to reduce noise, the values of adjacent pixels/voxels are averaged and detailed information concerning the contours of the bones may be lost, resulting in blurred images. On the other hand, with AiCE, which is trained to identify only noise that contains high-frequency components, noise can be selectively eliminated without affecting the contrast or signal values.

Figure 2 shows fat-suppressed proton density-weighted (PD-weighted) images. Compared to a 3 mm slice image (a), a 1 mm slice image with AiCE (b) depicts a partial tear of the supraspinatus tendon at the articular surface of the greater tubercle (circled area) more clearly due not only to a higher SNR but also to reduced partial volume effects in the thinner



0.2 × 0.2 mm resolution, 1.3 mm slice, PD FatSAT

Figure 1: Denoising effect of AiCE.

** Vantage Galan 3T / ZGO is not commercially available in all country.*

slice. In addition, the denoising performance of AiCE does not depend on the image type, because it has learned to identify only noise. Finally, AiCE can be applied not only to 2D images but also to 3D images.

Shorter examination times and higher resolution with Compressed SPEEDER

1. Technical features and clinical usefulness
Because scanning at a higher resolution generally requires a longer scan time, fast scan technologies are extremely important. Compressed SPEEDER is a fast scan technology which combines compressed sensing (CS) and parallel imaging (PI). The use of Multi-sensitivity Maps in PI increases the accuracy of unfolding images by creating two or more sets of sensitivity maps per coil channel. Using these maps for interative calculation in CS further increases the accuracy of unfolding images and thus provides clearer images. In addition, Compressed SPEEDER does not cause aliasing artifacts, which is a problem in conventional PI (SPEEDER) even when the encoding direction is set to the long axis. These characteristics are very well suited to imaging in the field of orthopedics. Figure 3 shows PD-weighted images. Extrusion and a horizontal tear of the medial meniscus (arrow) seen in images acquired with a SPEEDER factor of 1.5 (scan time: 3:02) (a) are depicted with comparable clarity in images acquired with a Compressed SPEEDER factor of 3 (scan time: 1:36) (b).

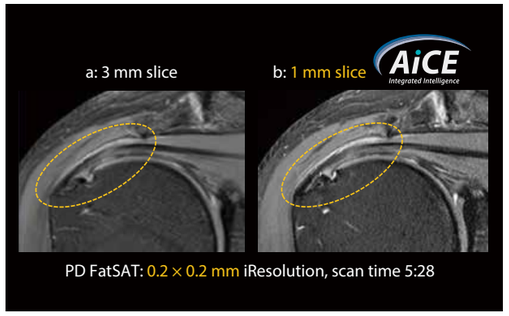


Figure 2: Application of AiCE to fat-suppressed PD-weighted images (partial tear of the supraspinatus tendon at the articular surface).

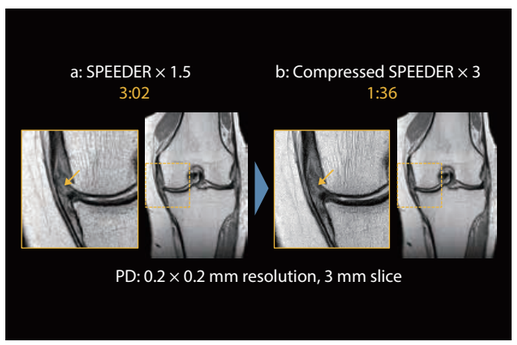


Figure 3: Comparison of PD-weighted images with SPEEDER (a) and PD-weighted images with Compressed SPEEDER (b) (extrusion and horizontal tear of the medial meniscus).

Compressed SPEEDER can be used for 2D fast spin echo (FSE), helping to reduce the total scan time in orthopedic MRI, in which 2D imaging is frequently employed. Taking advantage of the shorter scan time, it is also possible to select scan conditions that provide higher resolution. As shown in Figure 4, noise may be increased when Compressed SPEEDER is used for a low-SNR image (b, left). However, when AiCE is applied to the image, the labral tear (arrow) is visualized more clearly (b, right) with a shorter scan time than a SPEEDER image (a) while maintaining a high SNR.

2. Application to 3D imaging
Compressed SPEEDER can also be used for 3D imaging. For example, fast advanced spin echo (FASE) 3D T2-weighted images of the knee (0.5 mm isovoxels) can be acquired in a scan time as short as 3:48. Canon has developed a high-speed 3D scan technology known as “Fast 3D mode” which also achieves higher scan speeds while ensuring good image quality by adopting a unique k-space filling method and employing PI in combination.

On the other hand, some reports have described difficulties in visualizing medial meniscus injuries and posterior root tears of the lateral meniscus in 3D imaging.[1,2] This may be attributable to blurring due to a longer echo train spacing or low resolution.

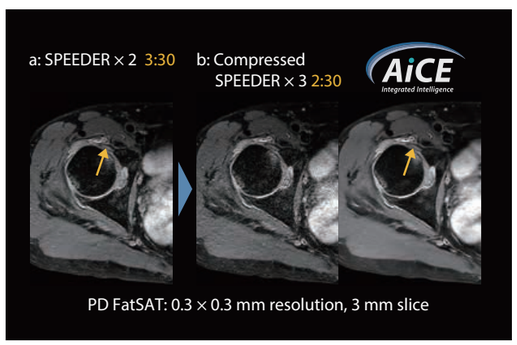


Figure 4: Fat-suppressed PD-weighted imaging with Compressed SPEEDER and AiCE employed in combination (labral tear).

3. Ideal MR images in the field of orthopedics
A broad outline of MR imaging can be summarized as follows. 2D imaging provides high in-plane resolution and is less affected by motion artifacts, but it is susceptible to partial volume effects due to the thicker slice thickness. 3D imaging allows thin-slice images to be acquired, and the acquired image data can be observed from any desired direction by multiplanar reconstruction (MPR), but it suffers from a number of disadvantages such as limited resolution, blurring, long scan times, and susceptibility to motion. Taking these basic characteristics into consideration, it can be said that ideal MR images in the field of orthopedics are high-resolution thin-slice 2D images that can be acquired in a short scan time. We have actually performed thin-slice 2D imaging with AiCE and have been able to obtain images that are sharper than 3D images in a shorter scan time.

Figure 5 shows a case of tibial osteonecrosis and chondral defects of the femur and tibia. Compared to a FASE 3D fat-suppressed PD-weighted image (Figure 5a), a 1-mm-slice FSE 2D fat-suppressed PD-weighted image with AiCE (Figure 5b) more clearly depicts the morphological characteristics of the osteonecrosis and chondral defects (circled area).

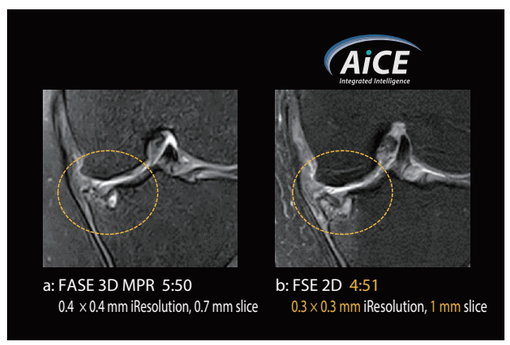


Figure 5: Evaluation of tibial osteonecrosis and chondral defects of the femur and tibia using a 2D thin-slice image obtained with AiCE.

Potential for quantitative evaluation using UTE Multi Echo

In diagnostic imaging, in addition to diagnosis based on qualitative images, it may also be necessary to perform evaluation based on quantitative data. Quantitative analysis can make it possible to detect abnormalities that cannot be seen in qualitative images, to identify lesions more quickly and thus improve prognosis, and to observe changes in lesions over time that may not be discernible in qualitative images. UTE technology, which enables scanning with a short TE of 0.5 ms or less,[3] can be used for quantitative analysis. In the field of orthopedics, tissues with a short T2* such as ligaments and tendons, for which quantitative analysis is difficult using conventional sequences due to low signal values, can be visualized and quantitatively evaluated.

In the UTE sequence, radial sampling is performed from the center of the k-space and signals are acquired from immediately after the RF half pulse, thus significantly reducing the TE. UTE Multi Echo allows multi-TE data to be acquired in a single scan, permitting T2* maps and scatter plots to be obtained in a short scan time (Figure 6).

With regard to the clinical applications of UTE, it has been reported that measurement of signals from a ROI placed in the patellar tendon showed a slightly higher T2* value in a patient with patellar tendinopathy than in a patient with a normal patellar tendon.[4] With UTE Multi Echo, the signal values obtained from multi-TE data can be used to make an excellent fitting curve in the monoexponential decay model (a model that assumes a single type of T2* in each voxel) or the biexponential decay model (a model that assumes two types of T2* [short T2* and long T2*] in each voxel). It is also possible to derive short or long T2* values.[5]

Conclusion

AiCE allows high-resolution imaging to be performed with a high SNR without prolonging the scan time. 2D images with a slice thickness of 1 mm (which are difficult to obtain using conventional techniques) can now be acquired with AiCE in a practical scan time, which substantially enhances diagnostic capabilities.

Compressed SPEEDER can reduce the scan time with no deterioration in image quality, permitting both shorter routine examination times and higher resolution. Both AiCE and Compressed SPEEDER can be employed for all types of images, 2D and 3D. Fast 3D mode is also useful as an option for high-speed scanning.

UTE Multi Echo enables quantitative evaluation of the tendons and ligaments and shows potential for the detection of abnormalities that cannot be visualized in qualitative images. //

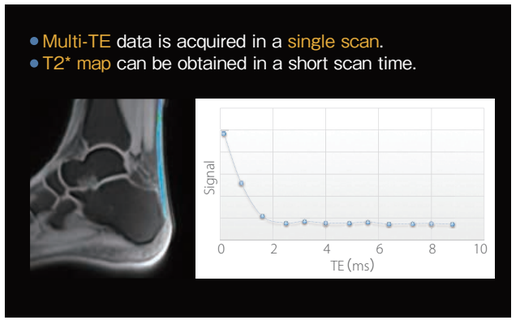


Figure 6: T2 map and graph obtained using UTE Multi Echo (WIP).*

Takahide Kakigi, M.D., Ph.D.
Department of Diagnostic Imaging and Nuclear Medicine, Kyoto University Graduate School of Medicine

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Reconsidering "Standard MR Images": What are the Ideal MR Images for Diagnosing Lesions in the Central Nervous System?

Toshiaki Taoka, M.D., Ph.D.

MR imaging is routinely used for the diagnosis of lesions in the central nervous system. In this lecture, I would like to briefly discuss some key issues related to the acquisition of various types of MR images in terms of their diagnostic usefulness. At our hospital, a 3-T Vantage Centurian* MRI system (Canon) entered operation in November 2019. This system features a noise reduction reconstruction technology employing an advanced AI approach called Deep Learning Reconstruction (DLR) (product name: Advanced intelligent Clear-IQ Engine, AiCE). I would also like to show how this technology can be applied to images by presenting actual clinical images obtained at our hospital.

T2-weighted images

1. Image characteristics and the need to obtain coronal images

The main requirement for T2-weighted axial images is good contrast between various tissues, such as between the cortex and white matter, between white matter and central gray matter, between various nuclei in the brainstem, and between lesions and normal tissues. In order to clearly depict these structures, it is important to perform examinations using an appropriate scan sequence.

Obtaining T2-weighted coronal images is also essential. For example, the distribution of brain atrophy, enlargement of the inferior horn of the lateral ventricle, and widening of the collateral sulcus due to Alzheimer's disease can easily be identified in coronal images. The characteristic findings of normal pressure hydrocephalus, such as narrowing of the sulci in the parietal region (high convexity) and an increase in the callosal angle, can only be identified in coronal images. With regard to degenerative diseases, it is known that the normal cross-sectional area of the middle cerebellar peduncle is around 200 mm^2 in coronal images and that the angle of the superior cerebellar peduncle is significantly increased in patients with multiple system atrophy of the cerebellar type.

2. Shorter scan times with AiCE

The acquisition of coronal images is frequently omitted in routine clinical practice in order to shorten the examination time. Evaluation was conducted to determine whether AiCE can be used to shorten the scan time while maintaining an acceptable level of image quality for interpretation.

Figure 1 shows a comparison of coronal images with and without AiCE. The images in rows c and d were obtained by applying AiCE to an image acquired in 50 seconds with NAQ 1 (a) and adjusting the strength and threshold. Extremely good image quality is obtained with a strength 5 and a threshold 1.2 (Figure 1d, center), but because AiCE only removes noise that contains high-frequency components,[1] CSF pulsation artifacts are still present in the image. In addition, the entorhinal cortex (arrow), which can be seen in the image acquired with NAQ 2 (Figure 1b), is not clearly visualized in the images acquired with NAQ 1, even with AiCE (Figure 1c, d). It is important to understand that structures which are not visible in the original image cannot be made visible by applying AiCE, therefore AiCE must be used appropriately.

** Vantage Centurian is not commercially available in all countries.*

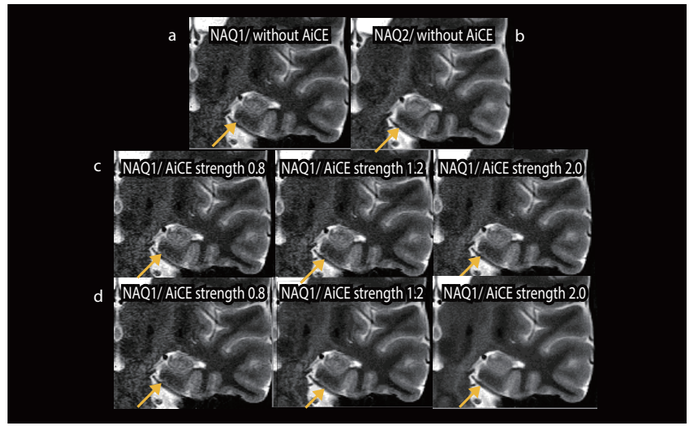

Figure 1: Shorter scan times for T2-weighted coronal images with AiCE.
a: NAQ1 / Without AiCE
b: NAQ2 / Without AiCE
c: NAQ1 / AiCE strength 1
d: NAQ1 / AiCE strength 5

T1-weighted images

1. Changes in visualization with different scanning methods

There are a variety of scanning methods for acquiring T1-weighted images, such as spin echo (SE), fast spin echo (FSE), and T1FLAIR. It is therefore important to take the scanning method into consideration during image interpretation. For example, the severe calcification in the basal ganglia and the deposition of gadolinium-containing contrast medium in the brain which are observed in patients with Fahr's disease may not be depicted by a scanning method that includes an inversion pulse. In contrast-enhanced MRI, the enhancement characteristics differ between sequences employing the inversion recovery (IR) technique and those employing the SE technique. Especially for the evaluation of metastasis, scanning using both SE and IR sequences reduces the risk of failing to detect lesions.

2. Usefulness of AiCE in detecting pituitary microadenomas

Although pituitary microadenomas can be clearly depicted in dynamic examinations, there are some limitations related to the slice thickness and the number of slices. Evaluation was conducted to determine whether AiCE can be used to obtain high-resolution images in a short scan time (Figure 2).

When AiCE was applied to images acquired with a slice thickness of 2 mm and an imaging interval of 30 sec (Figure 2a), a microadenoma (arrow) was clearly depicted in the image acquired at 30 sec (Figure 2b, center), demonstrating improved diagnostic capabilities. AiCE allows acquisition with a thinner slice thickness, which is extremely useful.

FLAIR

1. Image characteristics and the need to obtain FLAIR images

When TE = 100 ms, excellent contrast can be obtained in FLAIR images at around TR/TI = 10000/2200 ms. Therefore, a longer TR is preferred. As TE is gradually increased, overall signal intensity is reduced, but the differences in contrast between tissues with different levels of water content are increased.

In recent years, with the introduction of Synthetic MRI, some have argued that FLAIR imaging is no longer necessary. However, due to partial volume effects, boundaries are not clearly depicted in Synthetic FLAIR, and separate FLAIR imaging may be required. For example, signals related to flow-related phenomena such as intravascular high signal intensity can be depicted only by 2D-FLAIR.
In addition, with regard to lesions located near CSF, it has been reported that a group of patients with sporadic neuronal intranuclear inclusion disease showed symmetric high-intensity signal in the paravermal area of the cerebellum in FLAIR images.[2] Synthetic FLAIR is not suitable for the depiction of such diseases.
High signal intensity in the sulci due to dilatation of the pial blood vessels in patients with cerebral infarction or migraine is also a characteristic finding in FLAIR images.[3]

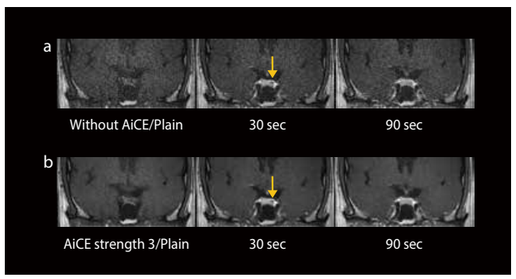

Figure 2: Application of AiCE in a dynamic pituitary examination (pituitary microadenoma).
a: Without AiCE
b: With AiCE

2. Utilization of AiCE

Because it takes some time to perform FLAIR scanning, evaluation was conducted to determine whether it would be possible to shorten the scan time (Figure 3). At TR/TE = 5000/100 ms, T1 contrast was significantly reduced and the abnormal low-intensity signals in the pons were lost (Figure 3a, center). To compensate for the reduction in T2 contrast, TE was set to 150 ms. Although contrast was improved with these scan conditions, overall signal intensity was reduced, resulting in poor image granularity (Figure 3a, right). When AiCE was applied to this image, not only the SNR but also the image granularity was improved, providing a diagnostically useful image in only 1 min and 10 sec (Figure 3b, right).

In contrast-enhanced T2-weighted FLAIR of the internal ear, the perilymph is usually enhanced about 4 hours after the injection of contrast. However, in patients with Meniere's disease associated with endolymphatic hydrops, the volume of non-enhanced endolymph is increased. Therefore, a subtraction image (HYDROPS image) was created from an image acquired with TI = 2250 ms (perilymph: high intensity, endolymph: low intensity) and an image acquired with TI = 2050 ms (perilymph: low intensity, endolymph: high intensity). When AiCE was applied to the subtraction image, enlargement of the endolymphatic space was clearly observed (Figure 4).

T2*-weighted images

Multi-echo T2*-weighted images, which are often used in the field of orthopedics, are obtained by acquiring and summing multiple echoes. These images feature high SNR and high T2*-weighted contrast. It has been reported that this method provides not only excellent contrast between white matter

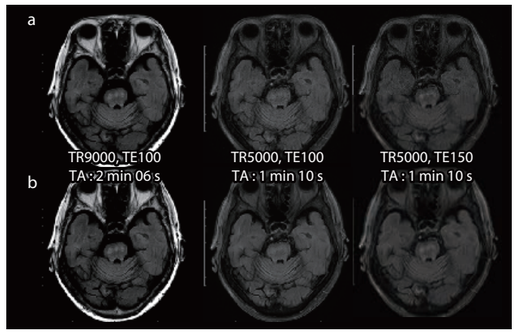

Figure 3: Shorter scan time in FLAIR with AiCE (multiple sclerosis).
a: Without AiCE
b: With AiCE

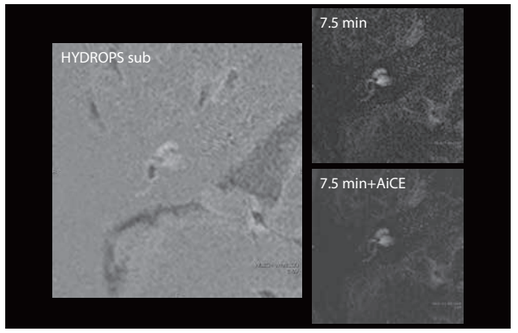

Figure 4: Depiction of an enlarged endolymphatic space in contrast-enhanced FLAIR of the inner ear (Meniere's disease)

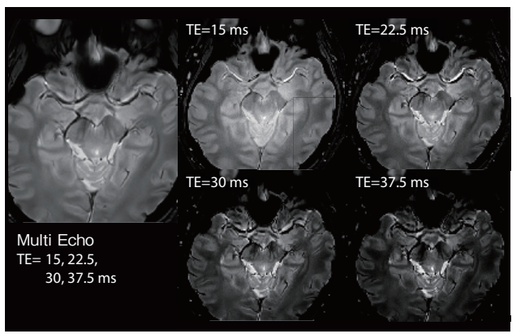

Figure 5: Visualization of nigrosome-1 in multi-echo T2-weighted images (normal subject)*

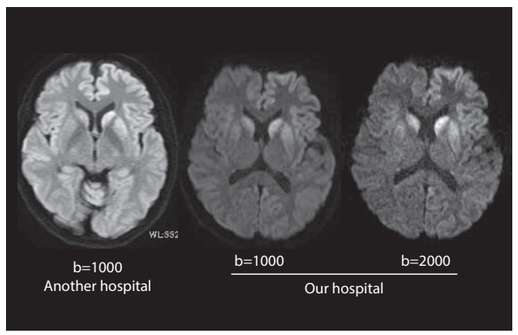

Figure 6: Depiction of Creutzfeldt-Jakob disease in diffusion-weighted images acquired with a high b-value.

and gray matter but also superior detectability of multiple sclerosis compared to SE.[4] Evaluation was conducted to determine whether multi-echo T2*-weighted imaging is useful for visualizing nigrosome-1 (Figure 5).

In patients with Parkinson's disease, signals from nigrosome-1 are unclear due to degeneration of the dopamine-containing cells.[5] It is often difficult to visualize nigrosome-1 even using 3-T MRI. At our hospital, multi-echo acquisition was performed in a normal subject using Vantage Centurian. When AiCE was applied, nigrosome-1 was very clearly depicted (Figure 5, left).

Diffusion-weighted images

1. Usefulness of imaging with high b-values
In diffusion-weighted imaging, the contrast in the normal cortex is reduced and the visualization of lesions is improved by employing a high b-value (b = approx. 1000 s/mm^2 in 1.5-T MRI, and b = approx. 2000-3000 s/mm^2 in 3-T MRI). With a high b-value, the visualization of lesions such as those associated with Creutzfeldt-Jakob disease (Figure 6) and cerebral infarction is improved, and some studies have even reported high detectability of acute-stage disease. In addition, because this method is not as strongly affected by T2 shine-through, the interpretation of diffusion is quite easy even in pathological conditions in which both increases and decreases in diffusion are observed, such as venous infarction. Scanning with a high b-value is considered to be extremely useful.

2. Effects of TE
The TE in diffusion-weighted imaging is related to the length of the diffusion time (TD). To obtain a higher b-value, a higher gradient or a longer TD is needed. However, a longer TD results in a lower SNR.

In Vantage Centurian, TE can be reduced to the range of 60-70 ms in diffusion-weighted imaging thanks to the strong gradient magnetic field (G_{max}). If TE is too short, cerebral infarcts exhibit low signal intensity even though high-SNR images can be obtained. On the other hand, if TE exceeds 90 ms, the SNR falls. Flexible parameter setting is possible in systems with a high maximum gradient field strength. Based on a clear understanding of these characteristics, the optimal TE for the detection of lesions should be carefully considered in clinical applications.

Conclusion

In this lecture, I have briefly discussed MR imaging of the central nervous system. Even though coronal and FLAIR images are often not acquired in busy clinical settings, such images can provide very important clinical information and should therefore be acquired even if the contrast and SNR are reduced to some extent because a short scan time is employed.

AiCE can be applied to a variety of sequences and is useful for improving image quality in scanning with short scan times and for clearly depicting fine structures. //

Toshiaki Taoka, M.D., Ph.D.
Department of Innovative Biomedical Visualization (iBMV), Graduate School of Medicine, Nagoya University

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Advanced intelligent Clear-IQ Engine (AiCE) Permits Diagnosis Using 1.5T Images that are Comparable to Images Acquired at 3T

Hiroshi Nakamura
Deputy Head of Diagnostic Radiology,
Shin Koga Hospital, Japan

Shin Koga Hospital, which is located in Kurume city, Fukuoka, Japan, is a core hospital which provides advanced medical care and emergency medical services in the Chikugo region. Because the hospital is committed to providing "emergency care that is ready for patients 24/7", it operates a comprehensive lineup of medical equipment to support rapid diagnosis and treatment.

With regard to MRI diagnostic services, the hospital has selected a 1.5T MRI Vantage Orian to replace one of its 1.5T scanners and has also installed Advanced intelligent Clear-IQ Engine (AiCE), an advanced noise reduction reconstruction technology incorporating AI for use in routine clinical practice. This first-hand report describes the benefits of AiCE in actual clinical use at Shin Koga Hospital.

Shin Koga Hospital.

Image quality comparable to that of 3T MRI

AiCE, which is one of the most outstanding features of Vantage Orian, achieves noise reduction by employing a reconstruction technique based on deep learning. Because the signal-to-noise ratio (SNR) is improved by this noise reduction reconstruction technique, scan conditions usually considered suitable only for a 3T scanner can be set without worrying about degradation of the SNR. Our decision to purchase a Vantage Orian system was mainly based on the benefits of performing examinations using a 1.5T scanner that offers outstanding clinical performance and operational efficiency as well as extremely high image quality previously achievable only with a 3T scanner, and the system more than met our expectations. Figure 1 shows images acquired using the same scan conditions as those for a 3T scanner. Images with a high SNR can be acquired in a short scan time.

More efficient operation with AiCE

In addition to our 1.5T Vantage Orian, we operate two other MRI systems (a 3T scanner and a 1.5T scanner). Because we have several MRI systems, it is a great benefit for us to be able to obtain images of comparable quality using our 1.5T and 3T scanners. Previously, we often found it troublesome to decide whether we should use a 1.5T or 3T scanner to perform a particular examination. Since the installation of AiCE in our Vantage Orian, because the image quality in now comparable to that of our 3T scanner, we no longer need to select a specific scanner when scheduling examinations. Of course, some specialized examinations such as brain tractography require use of the 3T scanner, but most examinations can now be performed using any of our scanners. This has resulted in more efficient operation and shorter examination times. Installation of Vantage Orian has therefore been a great benefit to our hospital.

It should also be noted that, compared to 3T scanners, 1.5T scanners suffer from fewer problems related to artifacts and the specific absorption rate (SAR). We are extremely pleased with our 1.5T Vantage Orian scanner because it can provide high-quality images comparable to those acquired at 3T. Figure 2 shows images of the brainstem. For head imaging as well, the quality of the images acquired by Vantage Orian is comparable to that of images acquired at 3T.

Easy parameter setting and simple system operation

The term "deep learning" may sound a little intimidating, but when conducting an actual clinical examination, the operator can turn AiCE on or off as easily as filter processing. In addition, AiCE can be set as a part of the scan sequence. This allows AiCE to be easily applied in routine examinations without any difficulties. Furthermore, because the degree of noise reduction can be adjusted for previously acquired images in order to provide the desired noise reduction effect, it is possible to adjust the images according to the preferences of the interpreting physician. Any differences in SNR between patients can be eliminated by adjusting the degree of noise reduction after the images have been acquired, thus ensuring a consistent level of image quality.

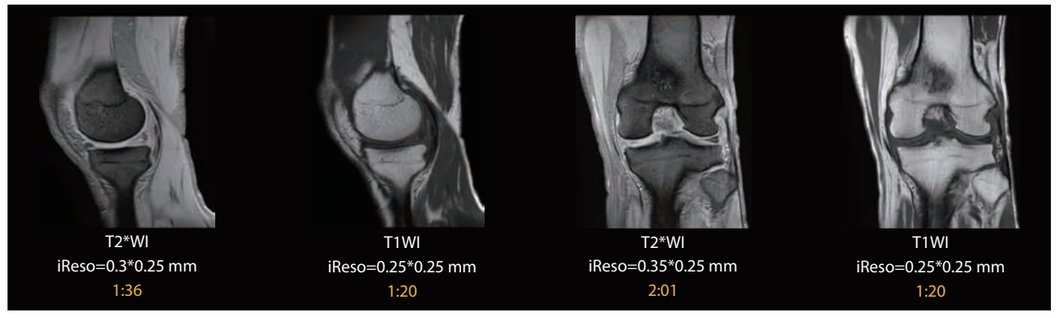


Figure 1

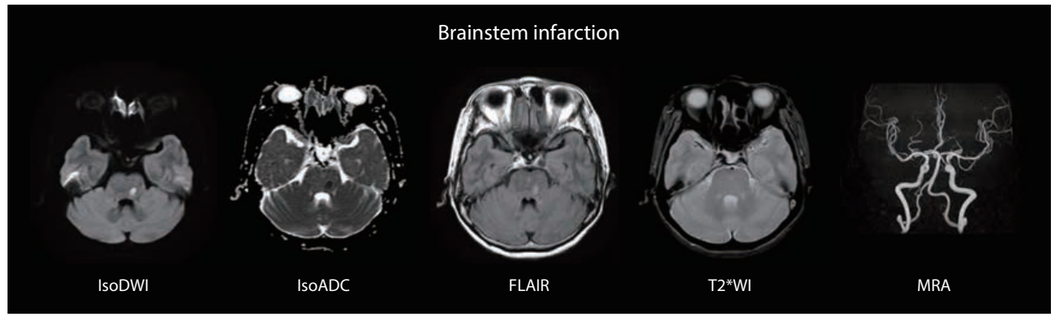


Figure 2

Technologies applicable to a wide variety of examinations

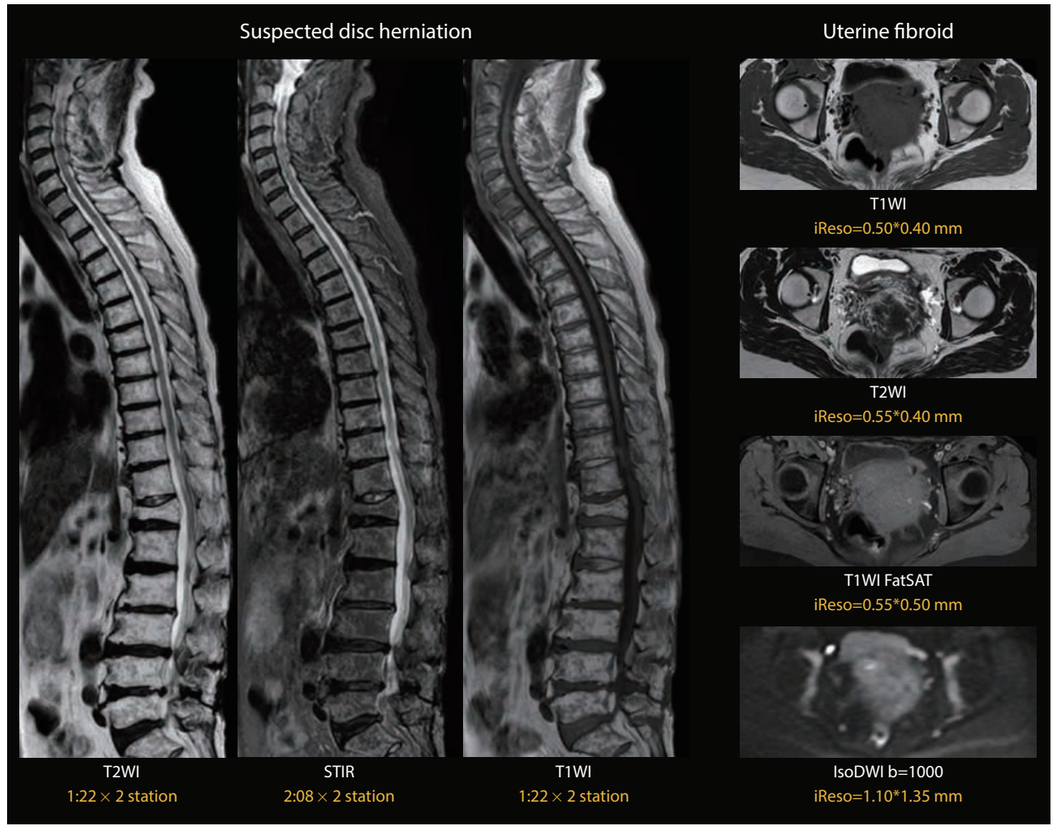
At our hospital, we perform examinations of all regions of the body, and we choose to employ AiCE in almost all cases. There are no limitations with regard to the coils that can be used or the image planes that can be selected. There are also no restrictions on the use of AiCE in combination with the compressed sensing technique or 3D high-speed scanning technique (Fast 3D mode). The technology is therefore very efficient and extremely versatile. The improvement in SNR is a great benefit, resulting in both shorter scan times and higher resolution. Taking full advantage of the above features, we employ AiCE for short-time wide-area imaging, for high-resolution imaging of the pelvis, and for many other types of imaging based on the specific diagnostic objectives of each examination.

Future prospects of AiCE

We expect the usefulness of Vantage Orian with AiCE to further expand in many fields in which a 1.5T scanner has sufficient performance capabilities. We have not yet had an opportunity to perform examinations of all regions of the body since the installation of our Vantage Orian, but we are aware that AiCE can be particularly useful in the field of cardiology for performing examinations such as MR coronary angiography (MRCA), cine MRI, and so on. We expect that our 1.5T Vantage Orian scanner will create new value that would be difficult for a 3T scanner.

We also plan to expand the applications of Vantage Orian to include non-contrast MRA for which we anticipate a strong increase in demand as well as whole-body examinations with short scan times, such as diffusion-weighted whole-body imaging. //

Clinical Images



Significantly Shorter Scan Times with No Degradation Image Quality Achieved with Advanced intelligent Clear-IQ Engine (AiCE)

Tomoaki Oshita
Radiological Technologist,
Department of Radiology,
Municipal Ozu Hospital, Japan

Municipal Ozu Hospital has 150 beds and is the main referral hospital in Ozu city, Ehime, Japan. Examinations of all regions of the body are performed based on requests received mainly from the departments of orthopedics, urology, and internal medicine. Municipal Ozu Hospital operates a high-end 1.5T MRI scanner, a Vantage Orian system. One year after the Vantage Orian system was installed, the hospital decided to upgrade their system by installing Advanced intelligent Clear-IQ Engine (AiCE), an advanced noise reduction reconstruction technology incorporating AI. This article is a first-hand report of the benefits of AiCE in actual clinical operation at Municipal Ozu Hospital.

Shorter examination times reduce the burden on patients and simplify scheduling

Many of the patients who visit Municipal Ozu Hospital are elderly, so we are always making efforts to shorten examination times and minimize the burden on our patients. At the same time, many referring physicians ask us to reduce the time required for each examination so we can schedule more examinations in the morning.

After our Vantage Orian was installed, the improvements in image quality were greatly appreciated by the physicians in each clinical department. The radiological technologists were also quite satisfied with the image quality. However, in response to requests from our physicians, 1 year after installation of Vantage Orian, we decided to upgrade the system by installing AiCE in order to shorten examination times without compromising image quality.

Following the installation of AiCE, we held discussions concerning image quality and came to the conclusion that taking measures to shorten examination times would provide a greater benefit to our hospital than producing images that exceed the those of a 1.5T. Currently, with the exception of certain specialized examinations, we schedule most Vantage Orian examinations in 20-minute time blocks. Many physicians at our hospital as well as visiting radiologists have commented on the outstanding quality of our images, particularly given the short scan times. As one example, a physician from Ehime University who regularly visits our hospital recently said, “Your MR images are so much better lately!”

Figure 1 shows images of the lumbar spine. After the installation of AiCE, scan conditions can be set with fewer acquisitions and shorter scan times. It is generally thought that significant degradation of the signal-to-noise ratio (SNR) is unavoidable when such scan conditions are employed, but AiCE allows examination times to be shortened while maintaining high image quality. Because avoiding degradation of the SNR is no longer such an overriding concern, scan conditions can be set with much greater flexibility.

AiCE can be used in combination with high-speed scanning techniques

Vantage Orian features a compressed sensing technique and a 3D high-speed scanning technique known as Fast 3D. By using Fast 3D and AiCE in combination, 3D magnetic resonance cholangiopancreatography (MRCP) examinations, which previously required respiratory-gated scanning for approximately 2 minutes and 30 seconds, can now be performed in a single scan with a breath-hold time of approximately 18 seconds (Figure 2). With AiCE, we do not need to worry about the SNR and can therefore employ high-speed scanning techniques with greater flexibility. Use of the compressed sensing technique included in the new system version allows us to achieve even shorter scan times.

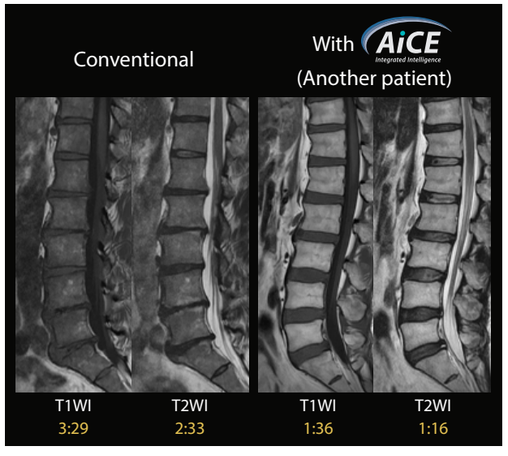
AiCE is used in most of our examinations

We use AiCE in most of our routine examinations, both 2D and 3D. Figure 3 shows images of the auditory nerves. These images were acquired in a scan time of 1 minute and 47 seconds, which is approximately half the previously required scan time of 3 minutes and 20 seconds. The image quality would be unacceptable without AiCE, but was significantly improved with AiCE. In addition, we were pleased to find that the time required for image reconstruction was actually shorter than when a conventional filter was used. This reduction in reconstruction time was quite surprising because we expected the reconstruction time to be longer due to the more complex reconstruction processing.

The operating procedures for AiCE are very simple. In the same way as filter processing, AiCE can be set as a part of the scan sequence or can be applied to previously acquired images in order to obtain the desired noise reduction effect. This allows us to deal effectively with any differences in SNR between patients.

Our ideas concerning image quality in routine examinations have changed

We previously had to take special care to ensure an acceptable SNR when setting the scan conditions. When AiCE was installed in our system, we had already gained a year of operational experience with Vantage Orian. This allowed us to determine how much we could shorten scan times while maintaining acceptable image quality based on direct comparison of images acquired by Vantage Orian with and without AiCE.



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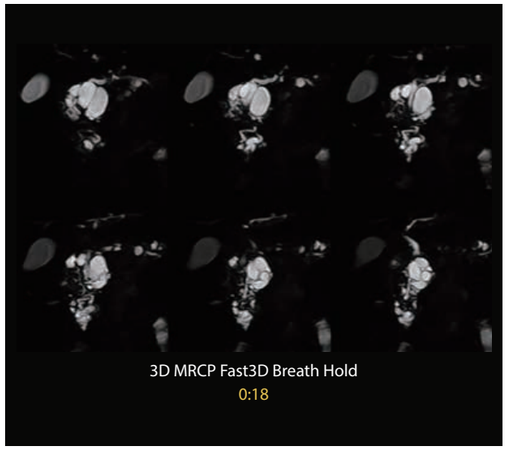


Figure 2

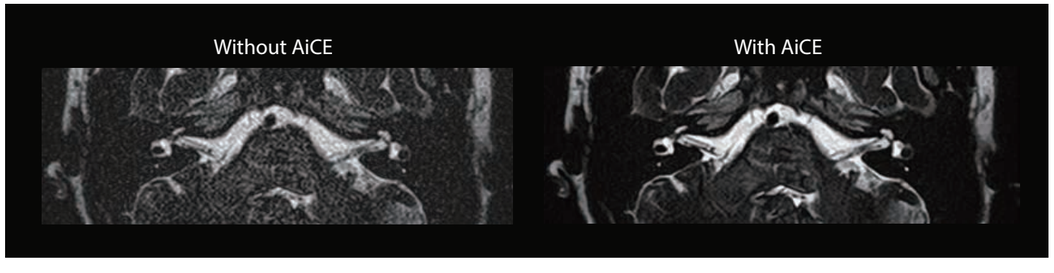


Figure 3

We gradually found that we could focus on selecting the optimal scan time and slice thickness while trusting AiCE to take care of the SNR. Of course, it is not possible to visualize things if suitable signals have not been obtained, and scan times should not be shortened without due consideration.

In abdominal examinations, rather than performing respiratory-gated scanning, we can now perform breath-hold scanning thanks to the shorter scan times made possible by AiCE. We care for many elderly patients at our hospital, and the ability to perform examinations in a short time is very helpful to us. Therefore, purchasing the AiCE upgrade was definitely the right decision for our hospital. In the ER, head examinations including MRA can be completed in approximately 7 minutes when AiCE is used.

We will continue to make efforts not only to reduce scan times, but also to improve resolution and to acquire images with thinner slices based on the diagnostic objectives of each examination.

We can perform more patient-friendly examinations

We designed the examination room in which Vantage Orian is installed with special care to minimize any discomfort that patients with claustrophobia or other health conditions might experience while undergoing MRI examinations. One of our top priorities was to create a comfortable examination environment for all our patients. To achieve this goal, we carefully selected relaxing wall finishes and room lighting and also installed the MR Theater. These efforts, together with the shorter examination times made possible by installing AiCE, have made it possible for us to provide even more patient-friendly examinations. //

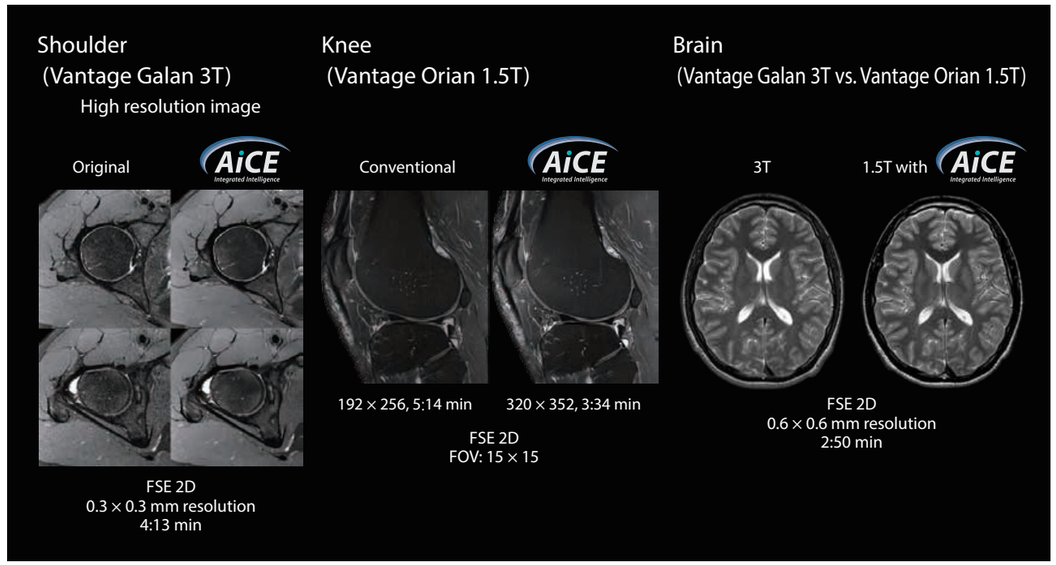
MRI system equipped with MR Theater.

Good to Know MRI

Advanced intelligent Clear-IQ Engine (AiCE)

Hung P. Do, PhD

WHAT?	A deep learning based reconstruction method for MRI that removes noise while maintaining feature integrity.
WHY?	To increase SNR of the reconstructed images. This increased SNR could be translated to increased resolution and/or shorten scan time. This could also enable high-field-like image quality without high-field challenges (e.g. higher cost, B_0 & B_1 inhomogeneity, etc.).
WHEN?	Applicable to all anatomies and available at both 1.5T and 3T, for both wide and narrow bore system.



HOW?

Advanced intelligent Clear-IQ Engine (AiCE) is a deep learning based reconstruction method, which was trained to differentiate noise from MR signal and then effectively removes noise while maintaining anatomical and pathological integrity. By design, AiCE was trained to remove only noise, which has distinct statistical property compared to that of anatomical and pathological features in MR images. The training data were not simply standard images but they were carefully prepared with 10 averages resulting in high quality training data with exceptional SNR, which would help to maximize AiCE's capability in differentiating noise from signal (features) hence effectively removing noise while maintaining feature fidelity.

As shown in Fig. 1, AiCE was designed based on the knowledge of MR physics and signal processing in combination with the power of deep learning, which results in an interpretable model with explainable robust and generalized performance. The denoising is only performed on the high-frequency components while the low-frequency components are untouched. That allows robust performance to contrast and signal variation in input images. The image sharpness, the denoising strength and the edge enhancement are the 3 options that can be tuned by changing the d0x, AiCE Adjust and Edge enhancement factors such that the reconstructed images match the users' preference.

To ensure safety and efficacy, AiCE underwent a rigorous validation process including bench testing, model observer study, and human observer study. Additionally, AiCE's performance could be assessed by comparing images with and without AiCE side-by-side and by inspecting the subtracted image. AiCE's model interpretability and transparency would allow the users to understand, trust, and confidently incorporate AiCE into clinical practice.

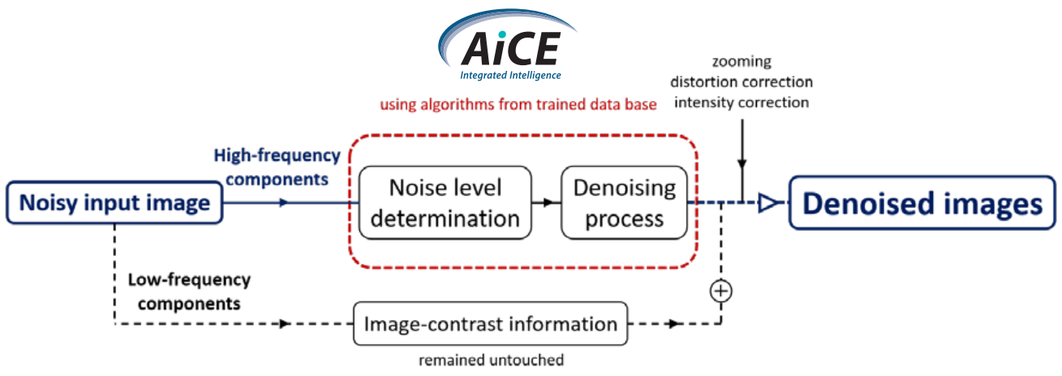


Fig. 1: Denoising Process in the clinical context

Precautions

AiCE should not be blindly applied to existing protocols. It is recommended to work with Canon clinical application specialists to identify the needs (whether throughput or SNR or resolution or a combination) and to understand how AiCE works and then to optimize the protocols so that it would maximize AiCE capacity and meet the desired expectation.

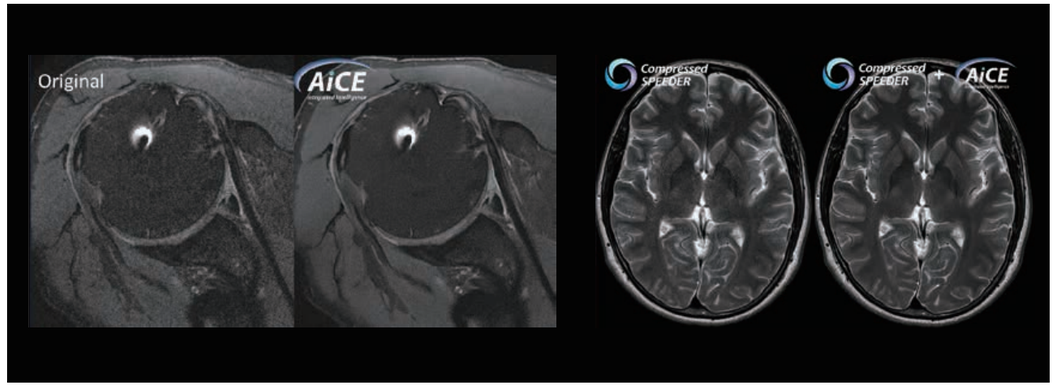
Tips, Tricks and best practices

- **d0x Factor:** Adjusts the image sharpness with a range of values from d01 (strong retention of natural sharpness) to d05 (weak retention of natural sharpness).
- **AiCE Adjust:** Determine the denoising strength. The AiCE Adjust could be set by the user to a lower or higher than the default value for weaker or stronger denoising, respectively.
- **Edge-enhancement:** The edges are sharpened through an additional unsharp masking. It is generally recommended to turn ON but must be turned OFF when performing image subtraction or when there is excessive motion artifacts.

Questions from the field

Q. Does AiCE work when there are abnormalities such as pathologies and artifacts

A. By design, AiCE was trained to only remove Gaussian noise so AiCE does not remove pathological features and (motion/metal) artifacts that has distinct statistical property from that of the noise.



Q. Does AiCE work with undersampled data?

A. AiCE does not directly transform undersampled data into the final output but AiCE is integrated into the reconstruction pipeline so that it could be combined with SPEEDER and Compressed SPEEDER, which directly reconstruct undersampled data for AiCE's inputs.

Q. Does AiCE preserve quantitative measurement such as T1, T2, etc.?

A. AiCE has been shown to improve SNR and CNR without changing quantitative values of T1, T2, and FA. See Prevost et. al., ISMRM 2020, Abstract #1878 for more detail.

Q. Is it possible to re-reconstruct AiCE with different parameters after the data is acquired?

A. Yes, as long as the raw k-space data is stored. The raw data is automatically retained for 48h, however, if the user would like to keep the raw data for longer period of time, please "lock" raw data option such that the raw data is stored until the "lock" option is un-selected. //

Hung P. Do, PhD
Manager Medical Affairs,
Clinical Scientist,
Canon Medical Systems USA, Inc.

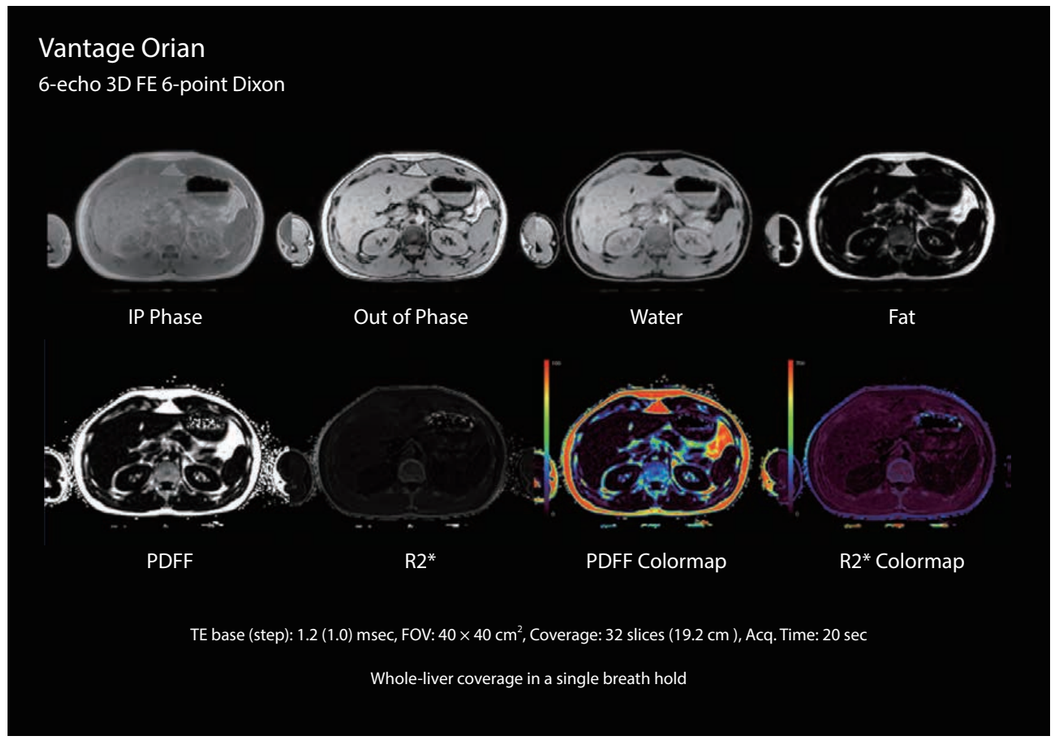
Fat Fraction Quantification

Mo Kadbi, PhD

WHAT? A single breath-hold multi-echo Field Echo scan to accurately and reliably measure Proton Density Fat Fraction (PDFF) and R2*, even in the presence of increased iron concentration.

WHY? To simultaneously provide, with one scan, quantitative maps of liver fat and R2*, in- & opposed-phase images, and fat- & water-only images.

WHEN? Quantifying hepatic fat content and iron accumulation is needed for diagnosis, severity grading, disease monitoring, or treatment response assessment.



HOW?

In general, a dual-echo FE sequence can be used for water/fat separation as explained in the Dixon Good to Know. PDFF can be measured using water/fat images (equation below); however the measurement is inaccurate due confounding factors such as T2* decay. A multi-echo FE sequence can be used to estimate R2* map and correct T2* decay. In addition, R2* map is affected by higher fat levels and needs to be corrected. FFQ is a technique to simultaneously estimate PDFF and R2* maps based on multi-echo FE imaging and correcting for the confounding effects.

Fat Fraction Quantification (FFQ): implementation and reconstruction

A: Canon has implemented a multi-echo breath-hold 3D FE sequence, utilizing data from six different echo times (TE), all processed without additional user interaction at the MR console.

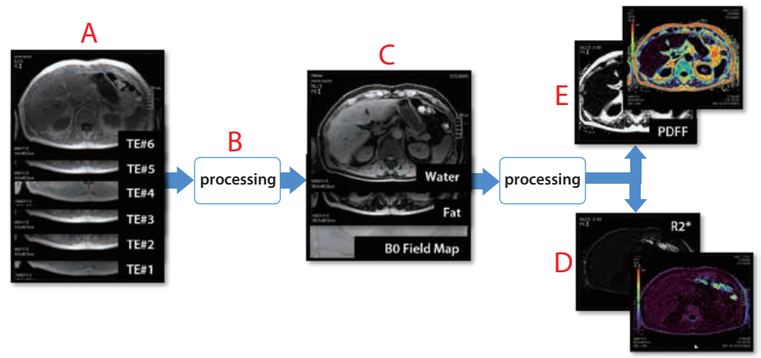
B: In-Phase (IP) and Out-of-Phase (OP) images can be generated easily using various combination of two images with different echo times.

C: From the six echo times, the reconstruction algorithm decomposes the signal into fat and water images. In order to achieve an accurate water/fat separation, B0 field map is estimated using the source images. The B0 map is then used to accurately separate water and fat signals.

D: R2* map is estimated jointly with the water and fat images after correcting confounding factors related to R2* estimation.

E: Those confounding factors impacting PDFF (e.g., R2* and multi-peak fat model) are addressed at this point. After calculation of corrected water and fat images and correcting the confounding factors, the PDFF is measured. The PDFF represents the ratio of MR-visible signal from fat protons to the sum of water and fat protons:

$$(\%)PDFF = 100 \times \frac{Fat_{\,corrected}}{Fat_{\,corrected} + Water_{\,corrected}}$$



Precautions

Artifacts can significantly impact the quantitative measurements:

- **Water/fat swap** can occur when the reconstruction misinterprets water signal as fat signal or vice versa. W/F swap can impact PDFF and R2* quantification depending on the severity and location of the swap.
- **SPEEDER edge artifact** can have a significant impact on PDFF measurements

Always investigate the images for any artifact and perform the analysis in an artifact-free ROI of organ tissue, away from vessels and ducts.

Tips, Tricks and best practices

- Acquire all scans using breath hold. Breath hold on exhalation is recommended for consistency.
- For the most robust acquisition possible, watch the waveform from the respiratory bellow for additional verification there is no more breathing motion.
- FFQ protocol can be specialized for patients suspected to have low or high iron content: base TE and TE steps need to be reduced when the iron level is expected to be high.
- The IP, OP, Fat, Water, PDFF, and R2* maps are automatically reconstructed and stored.

Questions from the field

Q. Why might we choose to use base TE of 1.2 msec vs much shorter?

A. The base TE of 1.2 msec is well suited for PDFF quantification. Additionally, R2* can be quantified accurately as long as the iron level is not too high. When iron level is high, the T2* (1/R2*) effect of iron causes the signal to decay rapidly and a shorter base TE should be used for R2* quantification to achieve higher SNR. Also flip angle (FA) is increased from 3 to 9 degrees to provide better SNR. Due to increased FA, the PDFF estimation is not accurate as a result of T1 effect. Therefore, the sequence with TE of 1.2 msec should be used for PDFF estimation.

Q. Why is the shim important?

A. FFQ estimates the B0 map in order to properly separate and quantify water and fat. The more homogeneous the B0 field, the more likely FFQ will be able to estimate it. Therefore, a high quality shim is important to ensure robust FFQ. Use FFE Shim variant to reduce impact of motion and susceptibility on shim.

Q. Are there some cofounding factors we have to take into account?

A. There are numerous widely recognized factors that can impact PDFF measurements – the accuracy of PDFF (and, in some cases, R2*) measurements depend upon the mitigation of each of these factors. Some of these confounding factors are:

- T1 effect: the relaxation time of water and fat are different, and that can cause significant bias in PDFF measurement. A shorter FA was chosen to reduce the T1 effect and generate Proton Density weighted images.
- T2* effect: in water/fat separation, it is assumed that the T2* decay between two echoes is negligible but in reality T2* decay may cause signal to vary rapidly between two echoes. T2* map was used to correct the T2* decay.
- Field inhomogeneity: may cause water/fat swap and impact PDFF measurement. An accurate B0 field map can help to eliminate this water/fat swap.
- Multi-peak fat model: an accurate fat peak modeling is necessary in PDFF measurement. The fat fraction can be more accurately calculated by using six-peak fat model, as Canon does.
- Phase error: using complex images to measure PDFF is sensitive to phase errors such as eddy current. On the other hand, magnitude images are not sensitive to phase error as the phase information is discarded but the dynamic range of measurement is limited. Canon employs a hybrid of magnitude and complex images can be used to achieve larger dynamic range with less phase error. //

Mo Kadbi, PhD
Manager Medical Affairs,
Clinical Scientist,
Canon Medical System USA, Inc.

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