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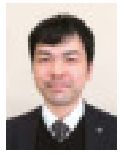
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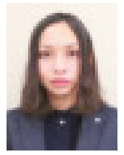
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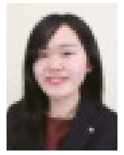
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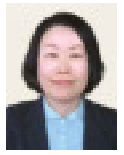
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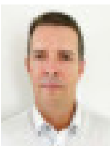
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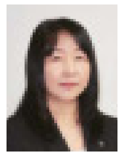
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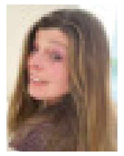
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The Creative Practice

// EDITORIAL

Dear Readers,

In reflecting on the year 2022, it can be said that we were still severely impacted by the COVID-19 pandemic. However, despite these challenges our mind-sets have been altered to survive in such a new era, and we now consider many aspects of life in alternate ways from how we traditionally did.

As is widely known, MR examinations can be very complicated, therefore highly experienced operators are usually necessary to provide high quality clinical images. It is said that 40 million new healthcare workers will be required in 2030, and with current calculations a shortage of up to18 million healthcare workers is predicted by that time. This environment means that the current direction of MR systems needs to change. Simplifying the workflow of MR exams is one of the most crucial topics we need to tackle as soon as possible.

In the past several years, we have been focusing on workflow improvements of MR examinations. We believe artificial intelligence (AI) technology combined with intelligent hardware such as Ceiling Camera and tablet UX can help us improve the entire MR examination workflow.

Recently, a new workflow solution has been introduced. This solution includes many new functions throughout the entire MR procedure, which could improve some pain points for operators. We hope this solution helps to reduce impediments during MR examinations and to greatly support healthcare professionals.

In conjunction with our clinical partners, we aim to continuously develop our MR systems in order to provide better solutions for ease of use.

I welcome you to enjoy reading our latest version of VISIONS Magazine Global Edition MRI Special, and we look forward to supporting your success in your clinical and healthcare journey.

MASAKI KAMIYA
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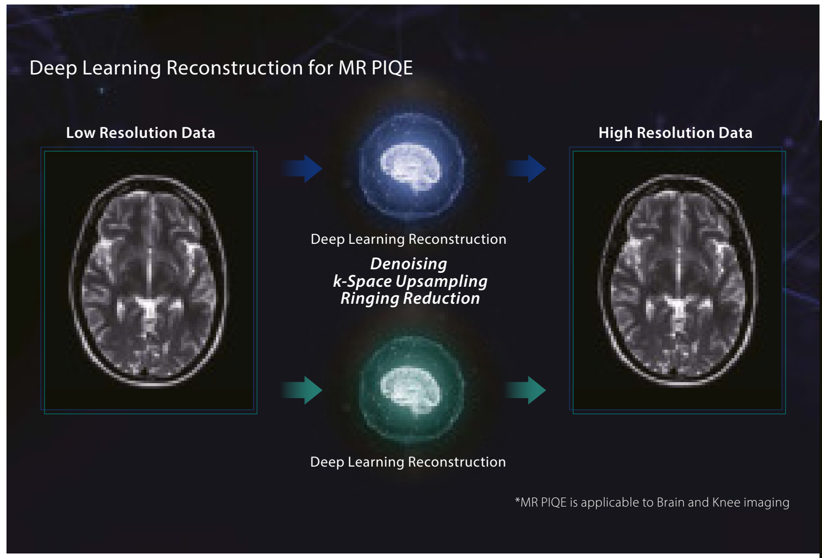
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Low Resolution Data
High Resolution Data
Deep Learning Reconstruction
Denoising
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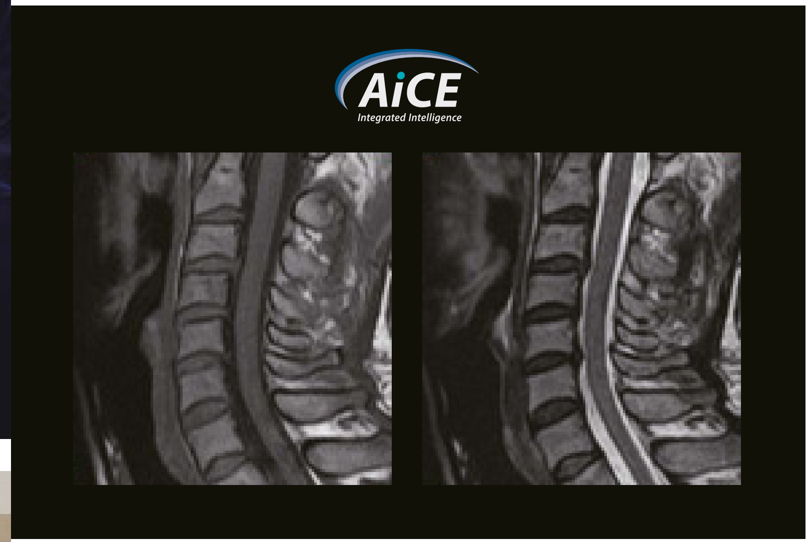
Ringing Reduction
Deep Learning Reconstruction
*MR PIQE is applicable to Brain and Knee imaging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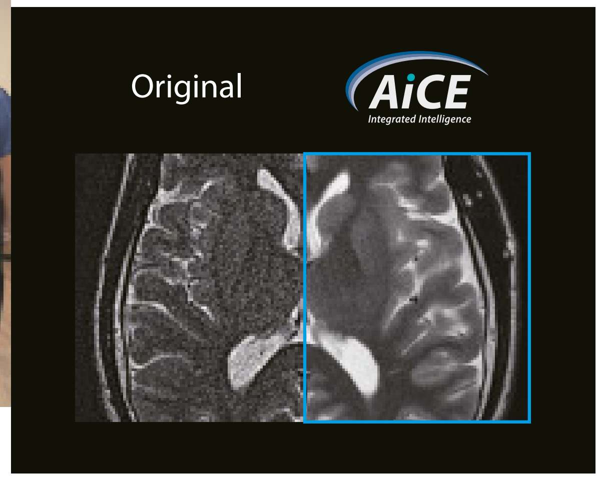
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The Future of MR Imaging

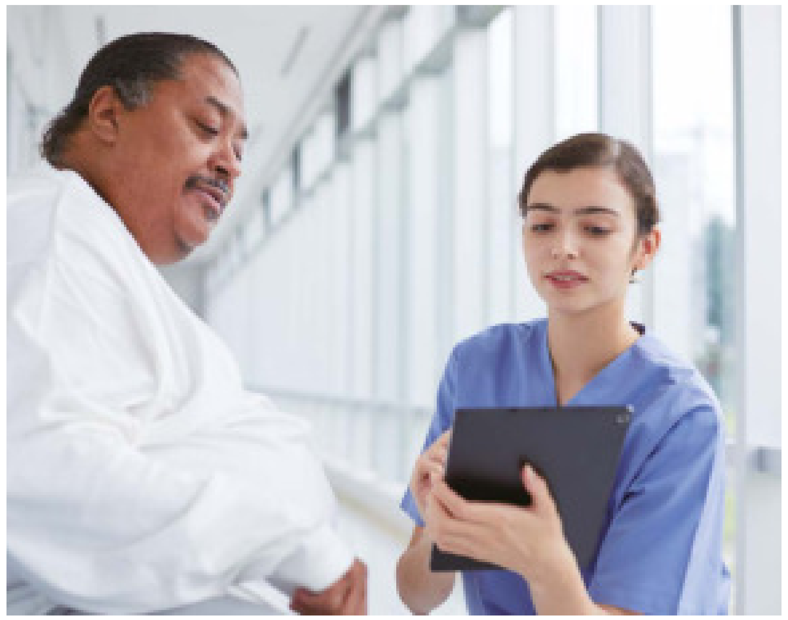
Rich Mather, Ph.D.

The complex physics at the heart of MR enables its greatest strength: the array of different image contrast mechanisms that make MR so versatile. MR can detect changes to the local magnetic environment due to the presence of iron, calcium, or hemoglobin. It can trace the diffusion patterns of water along microscopic tissue architecture and even measure the chemical exchange of magnetization between free and bound water molecules to probe macromolecular content. Despite all of this technical capability and success there are still two key issues that manufacturers can help solve to unlock MR's full global potential: patient access to drive healthcare equity among all communities and better workflow to streamline the diagnostic process.

The challenges of access to MR technology come from a range of different causes. For some patients, it is a matter of proximity, having to travel hundreds of miles to the nearest facility. For others, claustrophobia or physical size prevents them from being able to get an exam. Finally, for some, the exam cost can be preventative. Whatever the reason, limitations to access means that many patients with a clinical need for MR are unable to get one. In order to improve access, we need to minimize system cost and, more importantly, total cost of ownership. This will lower the barrier for smaller, more remote community clinics to install and operate an MR, increasing the geographic coverage. New system designs will better accommodate more patient shapes, sizes, and movement limitations as well as minimizing the opportunity for claustrophobia. Finally, MR scanners will be designed around ubiquitous high-speed networks to build an ecosystem of interconnected components that can help bridge across distributed healthcare informatics systems.

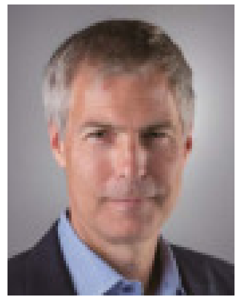
The other major challenge in MR is workflow. The flexibility that is inherent in MR systems comes at the cost of generating large datasets that capture multiple combinations of the many different possible contrast mechanisms. Acquisition speeds are slow compared to CT and ultrasound, making scheduling and patient throughput more challenging. Similarly, as access challenges are solved, scanner operation must be made simpler and faster to enable high-quality images without the need for highly-trained technologists and to allow higher volumes of patients to be scanned at busy clinics.

While there is a lot of hype around artificial intelligence (AI) in all industries, when applied correctly to the right problem, AI can manage complexity better than any conventional algorithm. In MR, several AI techniques are well suited to play a critical role in reducing cost and improving efficiency. Deep convolutional neural networks (DCNNs) do an excellent job of feature identification and discrimination. While a conventional algorithm might only use a small handful of hand-selected features like edge strength and noise amplitude over a 3×3 pixel patch of the image, by training to an image quality task, DCNNs can discover and combine millions of features over the entire dataspace and optimize their weights automatically to maximize image quality. A Deep Learning Reconstruction (DLR) network's ability to learn to discriminate between signal and noise in MR is a great example. The resulting noise-reduced images are far more natural-looking with higher resolution than any conventional algorithm could achieve. DLR approaches can reduce acquisition times and increase spatial resolution while preserving diagnostic quality.



AI will also play a key role in streamlining and simplifying MR workflow across the entire diagnostic process from patient preparation to scan planning to image acquisition and through image analysis and reporting. Preparing the patient for the exam is a critical step in ensuring both diagnostic quality and a good imaging experience. Getting key parts of this preparation done outside the scanner room improves scanner and radiographer resource efficiency. The introduction of AI-powered tablets that are integrated with the scanner console allows these critical resources to be focused on the patient throughout the process. These tablets can preload key patient and scan information, help to recommend and optimize scan protocols, and guide coil selection. Furthermore, optical Ceiling Cameras can feed patient and coil position information to the AI engine to optimize couch position for the best image quality. Once the patient is properly centered in the magnet, other AI networks begin the process of ensuring the best scan planes are used for the examination. These algorithms examine locator images, recognize the patient anatomy, and automatically plan the scan geometry and acquisition parameters. These technologies can help streamline the workflow for neuro, cardiac, liver, spine, knee, and other anatomies ensuring highly reproducible and standardized MR examinations that are independent of the experience of the radiographer. This reproducibility is especially critical for follow-up examinations so that identical scan planes can be acquired. During the scan acquisition, a combination of sensor hardware and AI will detect and correct for non-idealities in the magnetic field. This will not only help to further accelerate acquisitions, but may also allow for scanners to be sited in less restrictive environments. Next, once the scans have been acquired and reconstructed, AI quality control can examine the data for artifacts and other issues. Depending on the situation, these may be automatically corrected or could suggest a reacquisition to the radiographer. Finally, AI will help to manage what could otherwise be overwhelming data volumes. Image data will be automatically analyzed and clinically relevant findings will be identified. For example, in a stroke dataset, the perfusion/diffusion mismatch will be automatically calculated and a structured report will be generated. Urgent findings can be flagged and sent to the clinical team for confirmation and follow-up action, reducing the time to treatment. Similarly, algorithms like this can triage normal datasets and prioritize reading worklists for the reading radiologists. Each of these technologies will shave minutes off the diagnostic process and help to alleviate staffing pressure or allow for greater throughput in the busiest clinics. Ultimately, AI will streamline and simplify the entire MR workflow.

MR has the widest potential of any current imaging modality and should be available anywhere, anytime and to anyone. Cost, speed, complexity, and availability have limited this potential. The future technologies discussed here will democratize MR, opening global access and simplifying the workflow to manage the increasing demand without compromising on quality or cost. //



Rich Mather, Ph.D.
President
Canon Medical Research USA, Inc.

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This workflow solution is applicable to Vantage Fortian, some versions of Vantage Orian, Vantage Galan 3T, and Vantage Centurian.

Auto Populate

Shinsuke Komaki

As MRI examination is radiation free, it is widely used for follow-up examination to evaluate morphological changes in pathological conditions over time. In the follow-up examination, scanning should be performed at the same position (angle, slice thickness) and under the same scanning parameters as in the previous examination, so that the progression or the improvement of the lesion can be evaluated from the obtained images. Sometimes, it is not easy for inexperienced technologists to reproduce scan parameters and slice position/angle. Canon's new Auto Populate is a function that enables scanning to be repeated with the same angle, position, and parameters as previously. Auto Populate automatically sets the conditions so that variation between operators can be avoided and the examination is reproduced exactly.

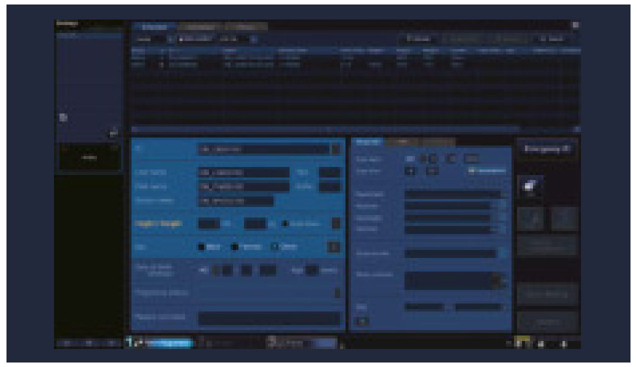

Figure 1: Patient registration screen

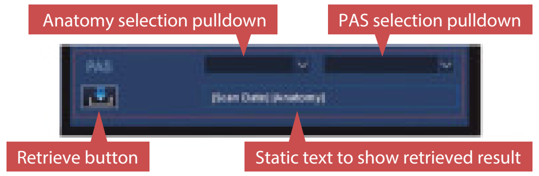

Figure 2: Enlarged view

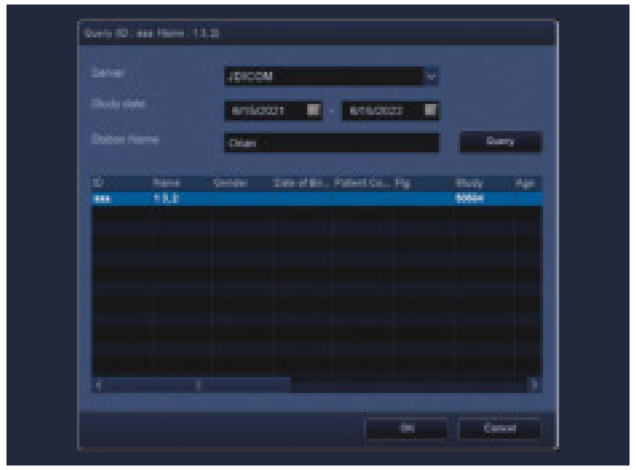

Figure 3: Query result display window

Retrieve a reference MRI study (image)

By clicking the retrieve button on the patient registration screen, the Query screen is displayed. On the Query screen, after entering the date of the MRI examination to be referenced, the query can be started (Figures 1 and 2).
The results of the query are displayed in the list (Figure 3). The proper examination to be referred can be selected and scan information is retrieved.

Restore scanning parameters

After the scan information is retrieved by the workflow above, the same PAS as the retrieved examination is loaded, and scan is performed with the same parameters as the ones in the previous examination.
By using this feature, it is possible to avoid the time and multiple steps required to reproduce the same slice location, angle coverage, and scan parameters manually.
Auto Populate can contribute to improve productivity and to take MR examinations to the next level of accessibility for everyone. //

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Auto Position for Seamless Patient Set-Up

Yutaka Hoshiyama

Conventionally, patient set-up follows these steps: projection of a red laser light and fine adjustment of the couch position to align the center of the coil (or the center of VOI) with the center of the laser light. However, this positioning takes time and, in some cases, causes increasing anxiety to patients when the couch moves back and forth in the process of adjusting the position.

Canon's new Auto Position is designed to enhance patient workflow by reducing patient set-up time, and give both the operator and the patient a greater sense of security.

The Ceiling Camera, which is focused on the preregistered scan region, provides the displayed coil setting position (center position), which is very helpful to the operator in preparing for the examination. Once the coil specified on the intelligent monitor has been set, all that is required of the operator is to select [MOVE] on the intelligent monitor to send the patient into the gantry, where the system automatically performs scan position setting. The previous manual scan position setting procedure and workflow is now fully automatic with Auto Position.

Auto Position utilizes AI technology to detect the scan position. The method begins by capturing an image using the Ceiling Camera, which shows the entire patient couch in the raised 'zero' position outside the magnet gantry. A Deep Learning method detects the patient's orientation. After that, the desired patient anatomy position (i.e. 'center position') detection is calculated based on the extracted information.

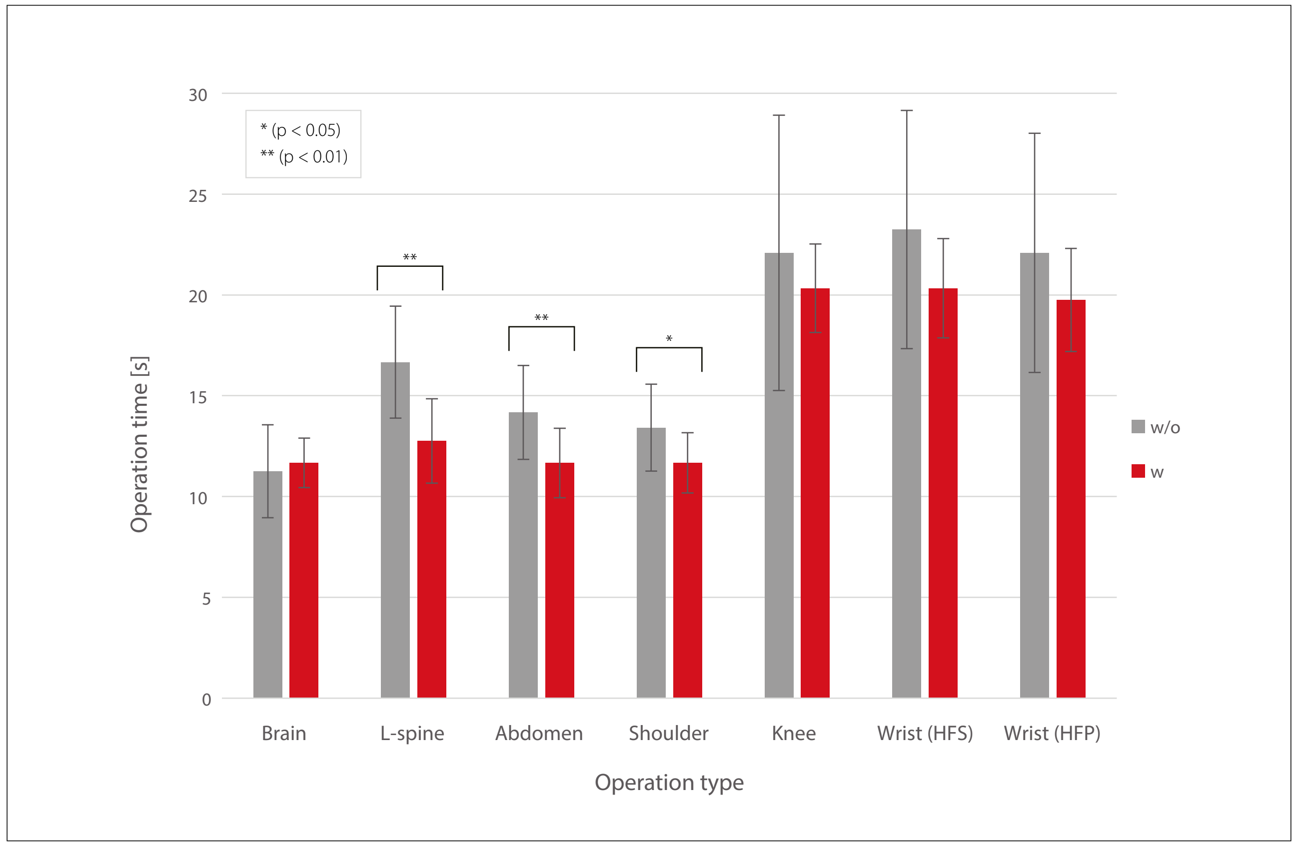


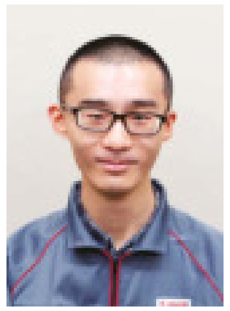
Figure 1: The operation time comparison of the patient setting with and without Auto Position

	Brain		L-spine		Abdomen		Shoulder		Knee		Wrist (HFS)		Wrist (HFP)	
Auto Position	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
Average (s)	11.3	11.7	16.7	12.8	14.2	11.7	13.4	11.7	22.1	20.3	23.3	20.3	22.1	19.8
Std	2.3	1.2	2.8	2.1	2.3	1.7	2.2	1.5	6.8	2.2	5.9	2.5	5.9	2.6

Table 1: The operation time and the variation comparison of the patient setting with and without Auto Position

Verification Study

A verification study was carried out to evaluate the clinical usefulness of Auto Position. In this study, the operation type was classified into seven body regions (Brain, L-spine, Abdomen, Shoulder, Knee, Wrist Head-First Supine; HFS, and Wrist Head-First Prone; HFP), for the entire procedure of patient positioning from coil setting, inserting couch through to iso center, and the operation time for each defined patient setting with and without the Auto Position was measured. The measurement of the patient setting was performed on two volunteers by six certified Radiological Technologists. This study showed that the operation time was similar or reduced by up to 20% compared without using Auto Position (Figure 1). Also, the variation of the scan time was shorter than a conventional setting (Table 1). This means that patient positioning can be performed successfully by anyone regardless of their level of experience.
In conclusion, Auto Position can reduce patient setting time for a more effective workflow, while reducing the variation of examination time between different operators. In addition, Auto Position can also contribute to reducing the patient's anxiety associated with the adjustment of the patient table, such as that caused by vibrations and laser light projection. //



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Auto Planning to Simplify Scan Planning

Yutaka Hoshiyama

There is a great need for highly reproducible MRI examinations with the same scan position and angle, and with smooth scan operation regardless of the operator's experience. Auto Planning, supported by Auto Scan Assist, allows MR Technologists with different levels of experience to perform complex MR procedures easily, while enhancing workflow and reproducibility from patient to patient.
Auto Scan Assist, slice positioning operation support function, is an AI-based application that automatically assists target plane setting*. Auto Scan Assist aims to support the reduction of operation time and to improve the reproducibility of scan plane without depending on the operators.

Currently, Auto Scan Assist supports the examination of the Brain, Cardiac, Liver, Spine, Whole Spine, Prostate, and Knee. Each function is commercialized as NeuroLine+, SUREVOI Cardiac/CardioLine+, SUREVOI Liver/LiverLine+, SpineLine+, W-SpineLine+, ProstateLine+, and SUREVOI Knee/KneeLine+, respectively (Figure 1).

Now, NeuroLine+ implements machine learning techniques instead of direct image analysis, such as symmetrical analysis and multiple-template-matching techniques to improve accuracy and robustness for a variety of head orientations and shapes due to individual difference. In Neuro MRI examinations, a middle Sagittal plane and Axial

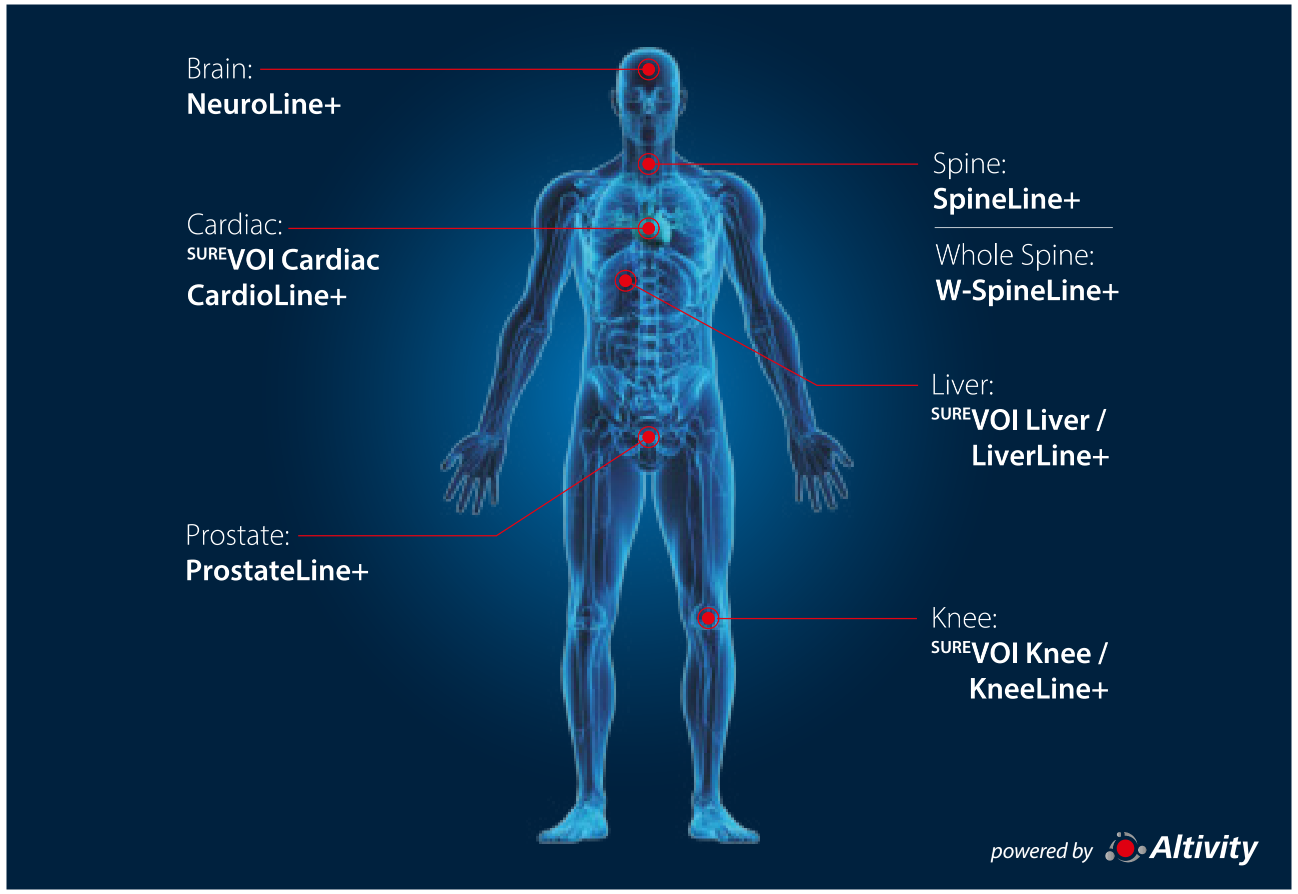

Figure 1: The examination regions supported by Auto Scan Assist

** Not all Auto Scan Assist features utilize AI.*

planes such as Anterior Commissure-Posterior commissure (AC-PC) line and Orbitomeatal (OM) line are basic planes, and NeuroLine+ detects those planes.

Verification Study

A verification study was performed to evaluate the clinical usefulness of NeuroLine+ in Auto Scan Assist. In this study, plane detection error defined by angular error was measured. The measurement of the plane detection error was performed for 13 patient datasets acquired with Canon's Vantage Galan 3T system. This study showed that the accuracy was improved compared to conventional NeuroLine+ (Figure 2). In addition, the operation time, and the operation steps for each head slice positioning with and without the Auto Scan Assist were measured. The measurement of slice positioning for the brain was performed on two volunteers by three different certified Radiological Technologists. The operation time was reduced by 63% and the operation step (the number of clicks) was reduced about 79% compared without using NeuroLine+ in Auto Scan Assist (Figures 3 and 4). In conclusion, Auto Scan Assist can reduce operation time while increasing reproducibility in order to enhance the users' and patients' MR experience. //

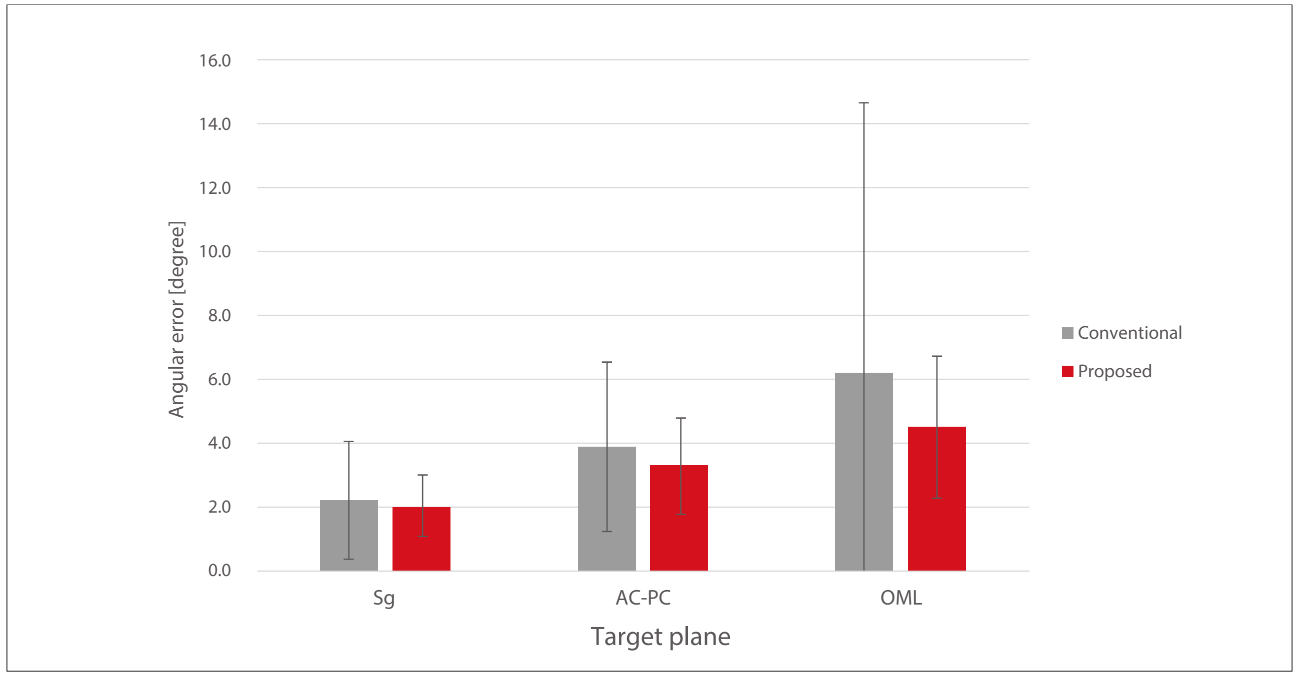

Figure 2: Angular error comparison between conventional method and proposed method.

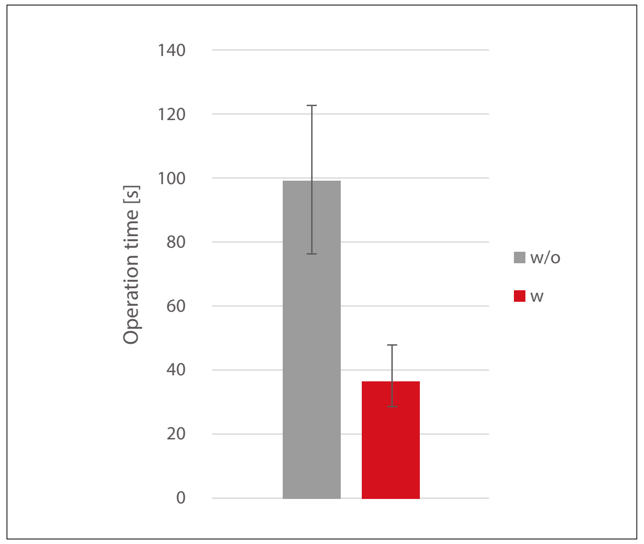

Figure 3: The operation time of the slice positioning with and without NeuroLine+ in Auto Scan Assist.

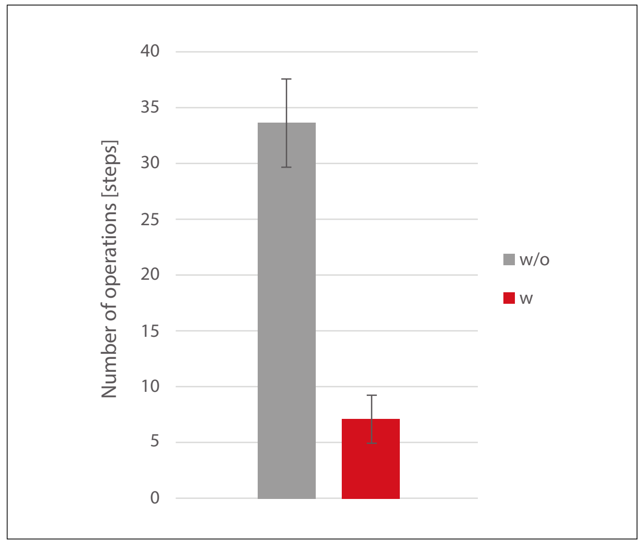

Figure 4: The operation steps of the slice positioning with and without NeuroLine+ in Auto Scan Assist.

Iterative Motion Correction

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Magnetic resonance imaging (MRI) is a relatively slow imaging modality. This can make motion unavoidable during patient scans. Motion can be sporadic, such as involuntary coughing and sneezing, or it can be continuous, such as breathing and cardiac motion. Such motion leads to image quality (IQ) degradation in the form of blurring, ghosting, and replication. In a study of 192 clinical examinations, Andre JB. et al.[1] found that 16.4% of scans were repeated due to poor diagnostic quality caused by moderate to severe motion. An example of IQ degradation due to motion is shown in Figure 1. The presence of motion artifacts can hinder clinical diagnosis. This can lead to rescans or patient callback, which further decrease patient comfort. Hence, there is a strong need to develop motion correction methods for MRI.

Motion correction methods are designed to maintain diagnostic IQ in the presence of motion, which will in turn reduce rescans and callbacks. Motion correction techniques can be broadly classified into (a) prospective and (b) retrospective methods. Prospective motion correction (PMC) techniques adjust acquisition position in real-time when motion is detected during scanning. PMC methods typically rely on navigators or external devices, such as cameras and fiducial markers, to estimate motion. PMC has high accuracy and is efficient because little to no data are discarded, however, it has limitations. Implementing PMC is challenging because it requires real-time calculation of motion parameters and real-time acquisition adjustments. Further, navigators are constrained by sequence design, and camera-based PMC can impede workflow by relying on external hardware and calibrations. Moreover, PMC methods only correct for rigid-body motion.

Retrospective motion correction (RMC) performs motion correction during image reconstruction. RMC needs neither external hardware to detect motion nor real-time feedback to update the acquisition process. Moreover, RMC can correct both rigid and non-rigid motion. Like PMC, data navigators can be combined with RMC for motion correction. RMC methods typically require little to no modification of workflow. These advantages make RMC a suitable choice for routine clinical use.

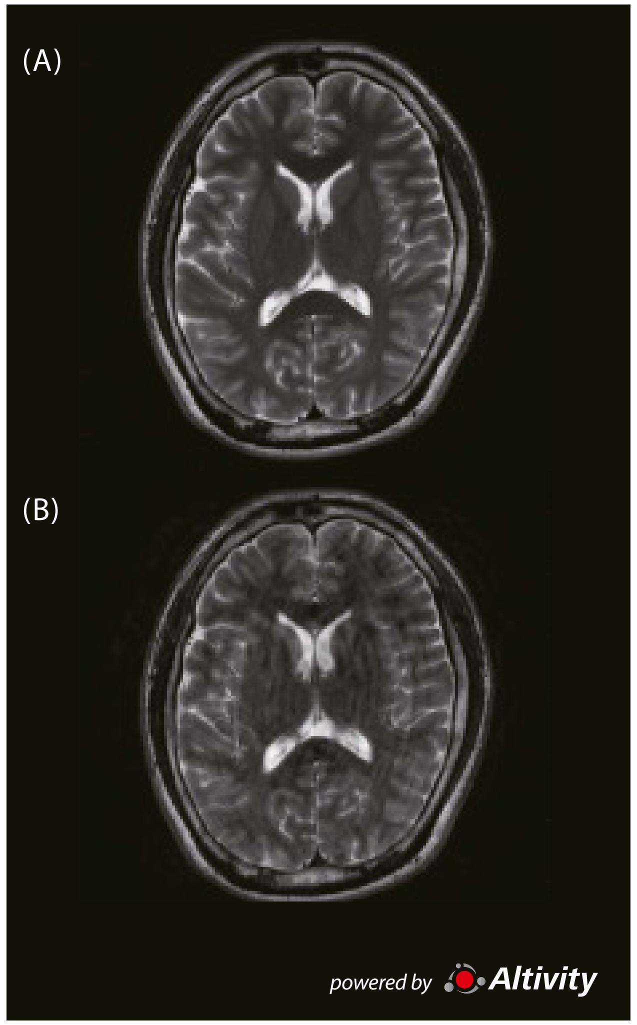

Figure 1: Example of axial T2W images without (A) and with (B) motion artifacts. In the case of (B), patient motion led to artifacts and non-diagnostic image quality.

Canon's JET is an RMC implementation for numerous clinical applications. JET uses radial acquisitions with overlapping blades. Data are acquired in parallel lines rotating around the center of the k-space. The overlapping data allows for the correction of motion. Despite its benefits, the radial acquisition produces artifacts such as streaking, image blurring, and a change of image contrast. Furthermore, radial sampling increases scan time compared to Cartesian sampling and can be applied to only a limited selection of contrast weightings. Therefore, alternative approaches for RMC are sought.

Canon has developed a new approach for robust RMC using iterative motion correction (IMC). IMC aims to improve IQ by incrementally updating the image. Canon's IMC focuses on maintaining diagnostic IQ in the presence of sporadic motion and can correct both rigid and non-rigid motion. An attractive feature of IMC is its use of Cartesian trajectories for data acquisition, which mitigates some of the challenges associated with radial acquisitions.

Canon released the initial version of IMC in their software release Version 8.0. The initial release of IMC supported motion correction for brain FLAIR and cervical spine T2W imaging. Canon's latest software release (V9.0) extends IMC to several new contrasts such as T2W and T1W brain imaging as well as T1W and STIR C-spine imaging.

The latest IMC release includes many technical improvements that are designed to expand its clinical applicability and reduce scan and reconstruction times. To improve robustness to motion, the shuffle encoding pattern used in the initial IMC release was retained. An example of the motion robust shuffle encoding pattern is shown in Figure 2. Conventional sampling approaches have uniform spacing of phase encoding lines for each shot, which causes coherent artifacts in the presence of motion (Figure 2A). As seen in Figure 2B, the shuffle encoding pattern has nonuniform spacing of phase encoding lines for each shot, and hence produces incoherent artifacts in the presence of motion. This is similar to the use of nonuniform sampling pattern in compressed sensing (CS). The latest IMC release reduces scan time by acquiring navigator data more efficiently and reduces reconstruction time by decreasing the reconstruction algorithm's complexity. Lastly, the latest IMC release complements the improved model-based approach with a new machine learning (ML)-based motion correction.

Several model-based motion correction techniques have been developed [2-4]. These methods integrate a physics model in the image reconstruction pipeline to reduce motion artifacts. Modelling motion parameters preserves the acquired data, which maintains signal to noise ratio (SNR). Despite their advantages, model-based methods can be limited by their long reconstruction times and the inability to correct for all motion types.

Recently, the strength and wide applicability of ML methods has been realized in several MRI applications [5-7]. ML offers a data driven approach for rapid motion correction. It does not rely on external hardware. Further, the modeling of motion, which can be computationally complex, is done only during the training stage. During runtime (inference), the ML network rapidly processes the image using the model that was learned during training. These advantages have driven the development of many promising ML-based solutions for motion artifact suppression [8-11]. However, ML may show reduced performance for motion not seen during training and may struggle to produce diagnostic IQ for cases with high motion.

Canon's new approach to motion correction combines model-based and ML-based approaches. This synergistic combination overcomes some of the limitations of each individual component. Additionally, this combined approach allows for greater robustness to motion than model-based or ML-based approaches applied individually. The new IMC release uses a complex-valued residual U-Net (Res U-Net) for ML (Figure 3). The ML network was trained on pairs of with/without motion datasets in a supervised learning framework.

An example of the improvement in IQ using the combination of model-based and ML-based approaches is shown in Figure 4. A coronal T2W image acquired in the presence of motion is seen in Figure 4A. Using only the ML network for motion correction does not produce a diagnostic quality image (Figure 4B) and motion artifacts and blurring still remain. Similarly, in Figure 4C, it is seen that some residual motion artifacts remain when only model-based motion correction is used. The best IQ is achieved when a combination of model-based correction and ML is used (Figure 4D).

IMC performance for several different contrasts is shown in Figures 5, 6, and 7. In Figure 5, an example of an axial T2 brain image is shown where the input image is corrupted due to motion. The use of IMC helped remove the motion artifacts and improved IQ. The different structures and features in the brain are better visualized in the IMC output. In Figure 6, the IQ benefits of IMC are shown in an axial T1W brain case demonstrating that the ringing artifacts caused by motion have been effectively removed with IMC. IMC can also be used for cervical spine imaging, an example of a sagittal STIR C-spine image is shown in Figure 7. The cord has significant motion artifacts when reconstructed without IMC. IMC recovered the IQ from the motion corrupted input image. These results show the effectiveness of Canon's latest IMC release for brain and cervical spine imaging applications. //

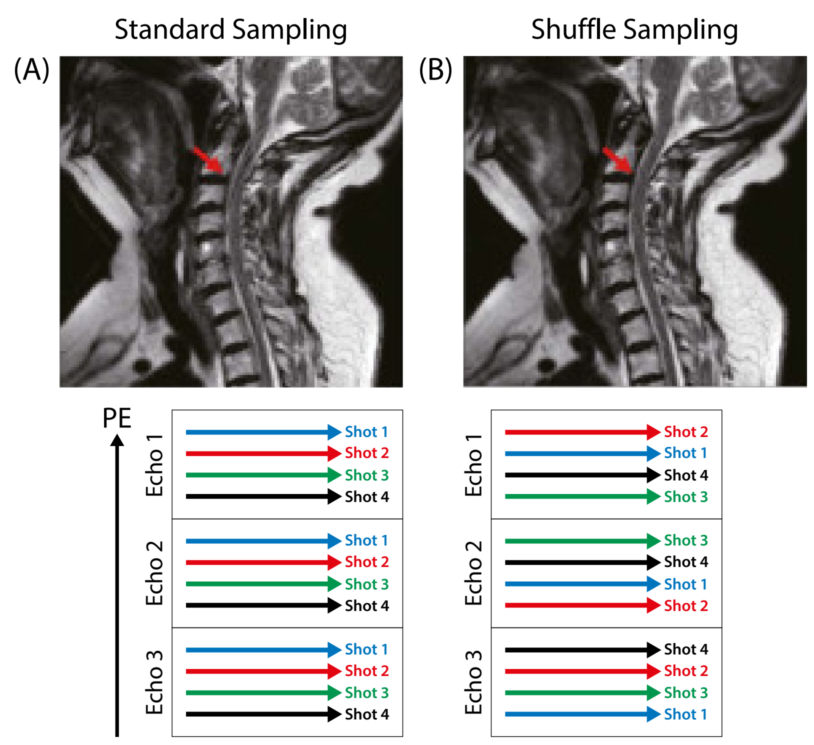

Figure 2: Standard sampling (A) and shuffle encoded sampling (B) are shown. Shuffle encoded sampling (B) exhibits lower motion artifacts compared to standard sampling (A) for in-vivo scanning (red arrows).

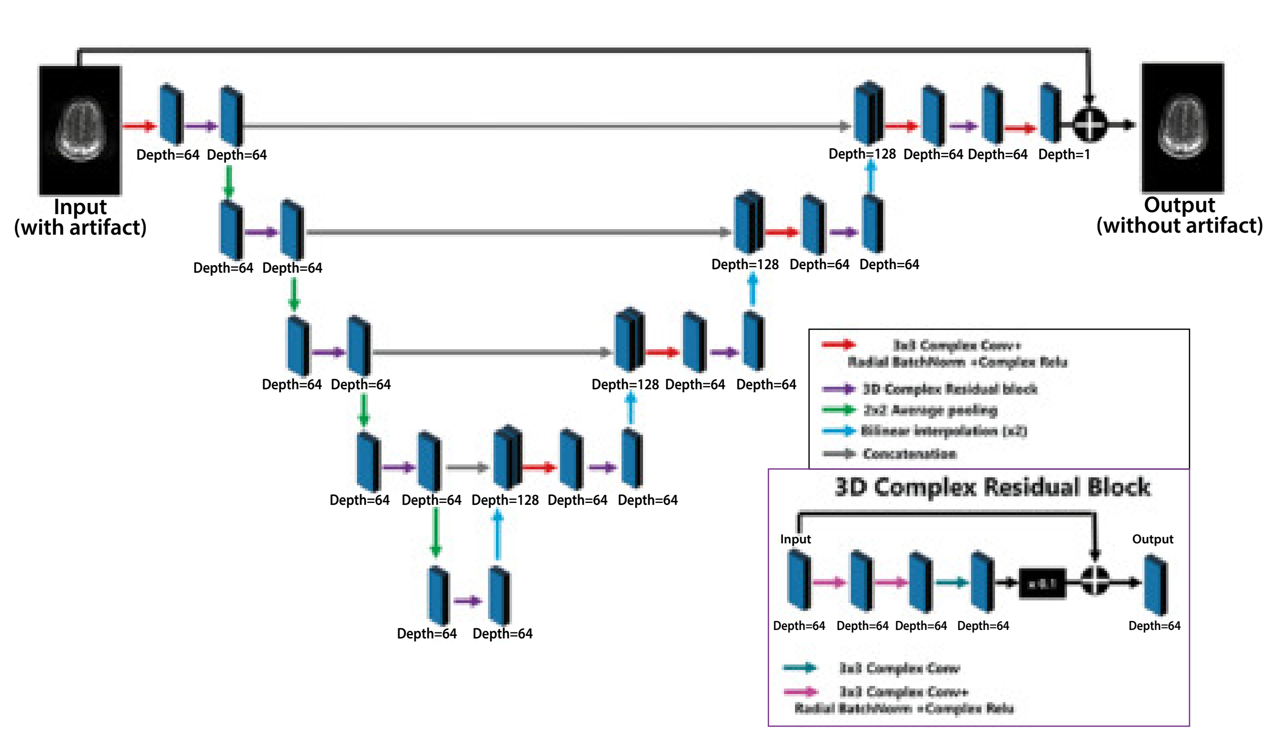

Figure 3: Architecture of the complex residual U-Net used for ML. The residual U-Net combines 3D residual block processing with the U-Net architecture to enable motion artifact suppression.

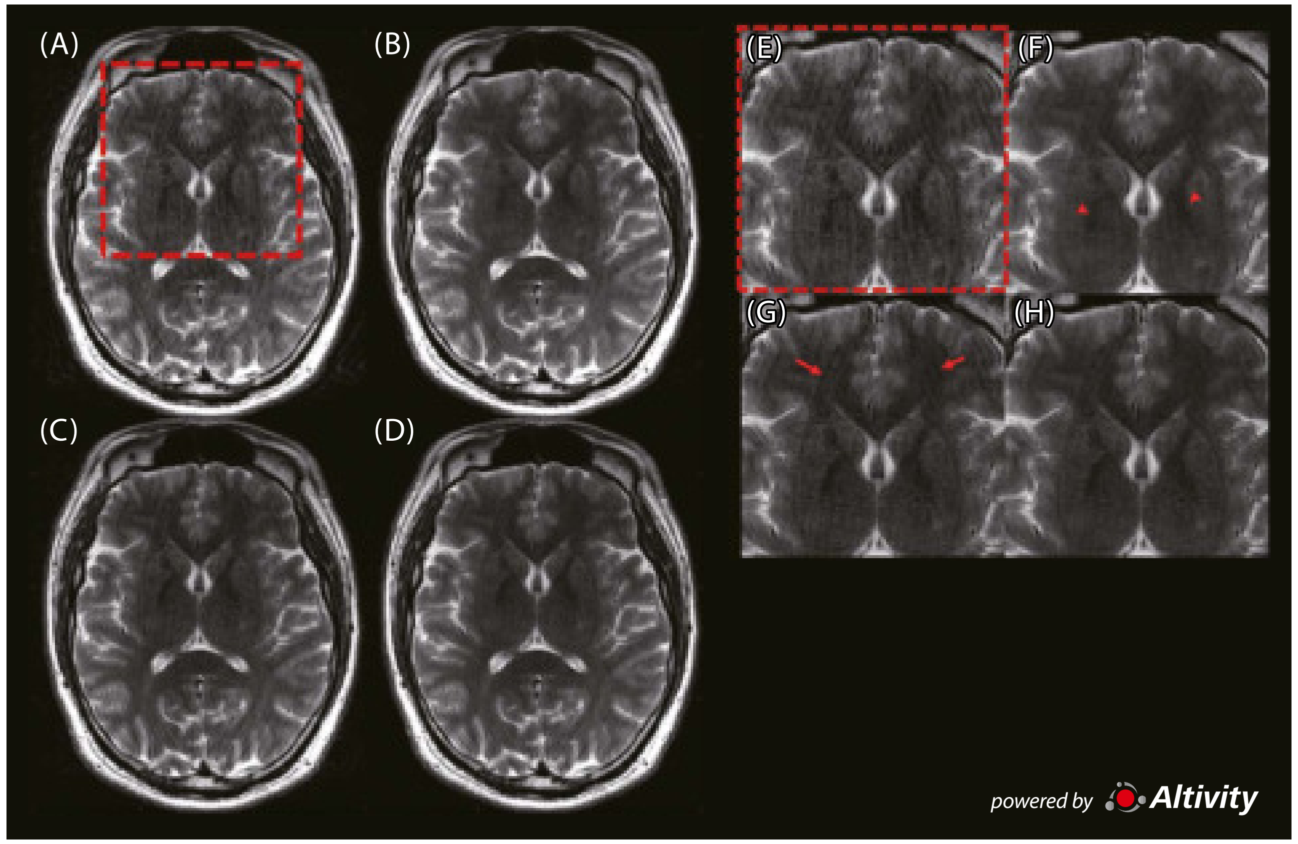

Figure 4: Coronal T2W image acquired in the presence of motion. Reconstructions are shown without IMC (A), with ML processing only (B), with IMC without ML (C), and with IMC (D). ML-only processing did not produce good image quality. Main features are blurred out (red arrowheads). The model-based method has remaining residual motion artifacts (red arrows). Combining model-based and ML processing produced the best IQ. (E)-(H) shows the zoomed-in image of a small region (indicated by the dashed red box in (A)) for (A)-(D) respectively.

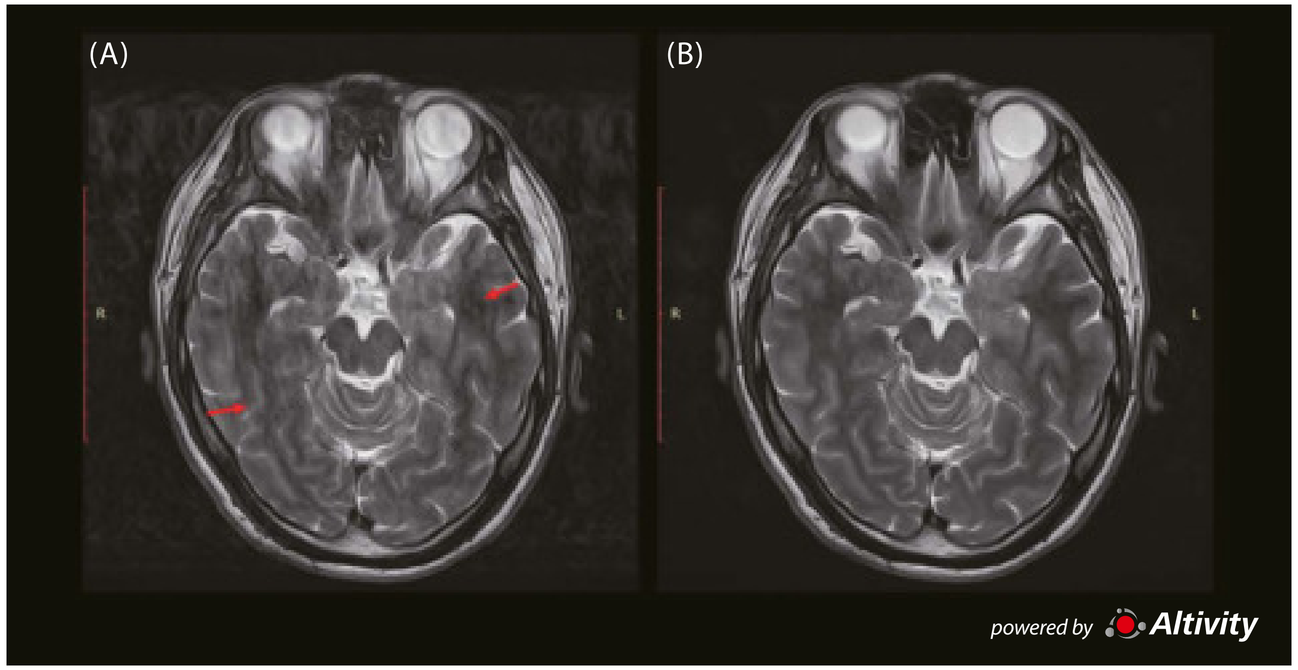

Figure 5: Axial T2W brain images processed without and with IMC. Without IMC (A), the image has artifacts because of patient motion (red arrows). Using IMC (B), IQ is restored, and the image is of diagnostic quality.

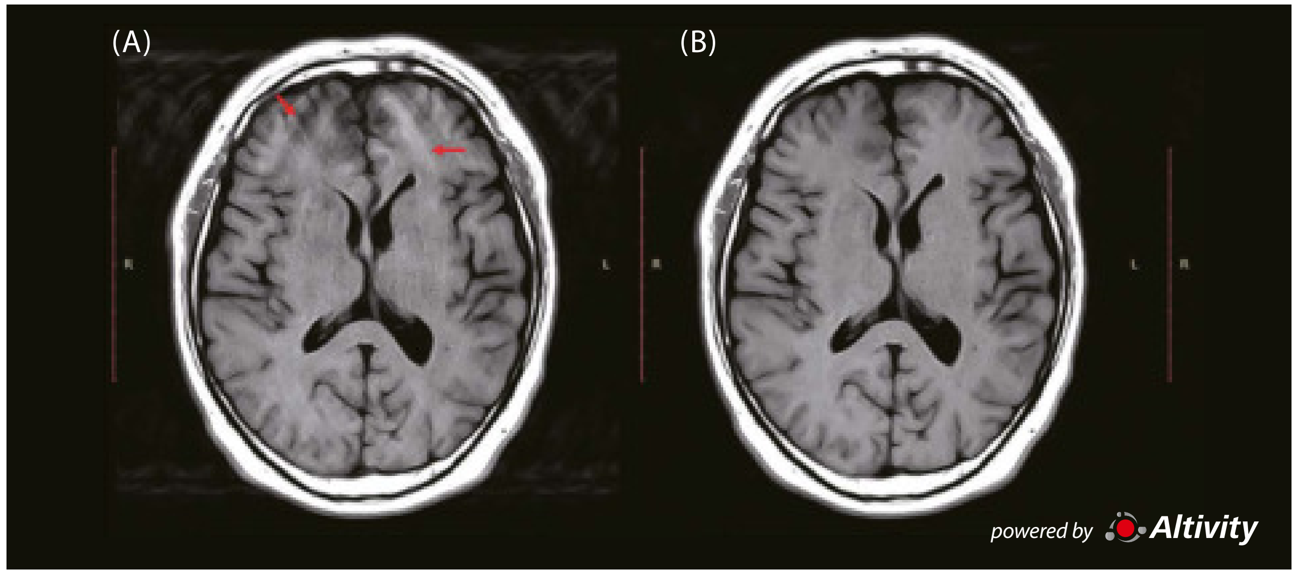

Figure 6: Axial T1W brain images processed without and with IMC. Without IMC (A), the image has artifacts because of patient motion (red arrows). IMC (B) significantly resolves the motion artifacts, leading to a diagnostic quality image.

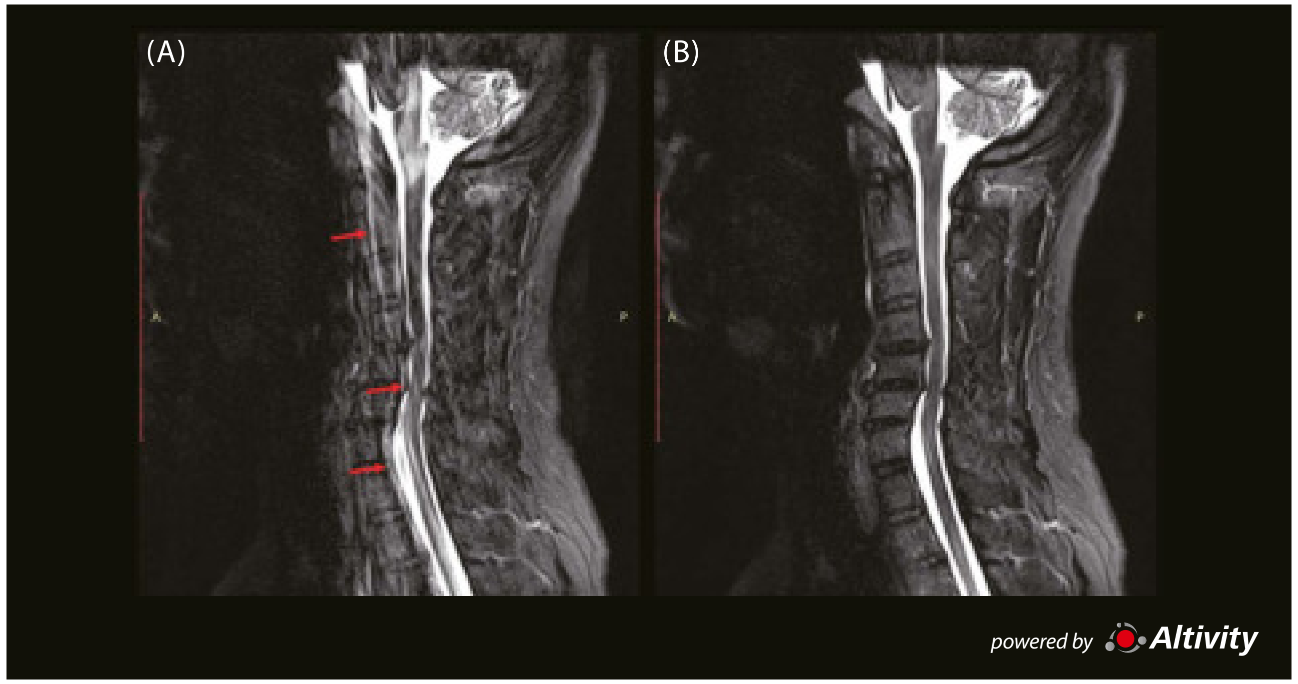

Figure 7: Sagittal STIR C-spine images without and with IMC. Without IMC (A), the image has artifacts due to motion during the scan (red arrows). IMC (B) significantly resolves the motion artifacts, leading to a diagnostic quality image.

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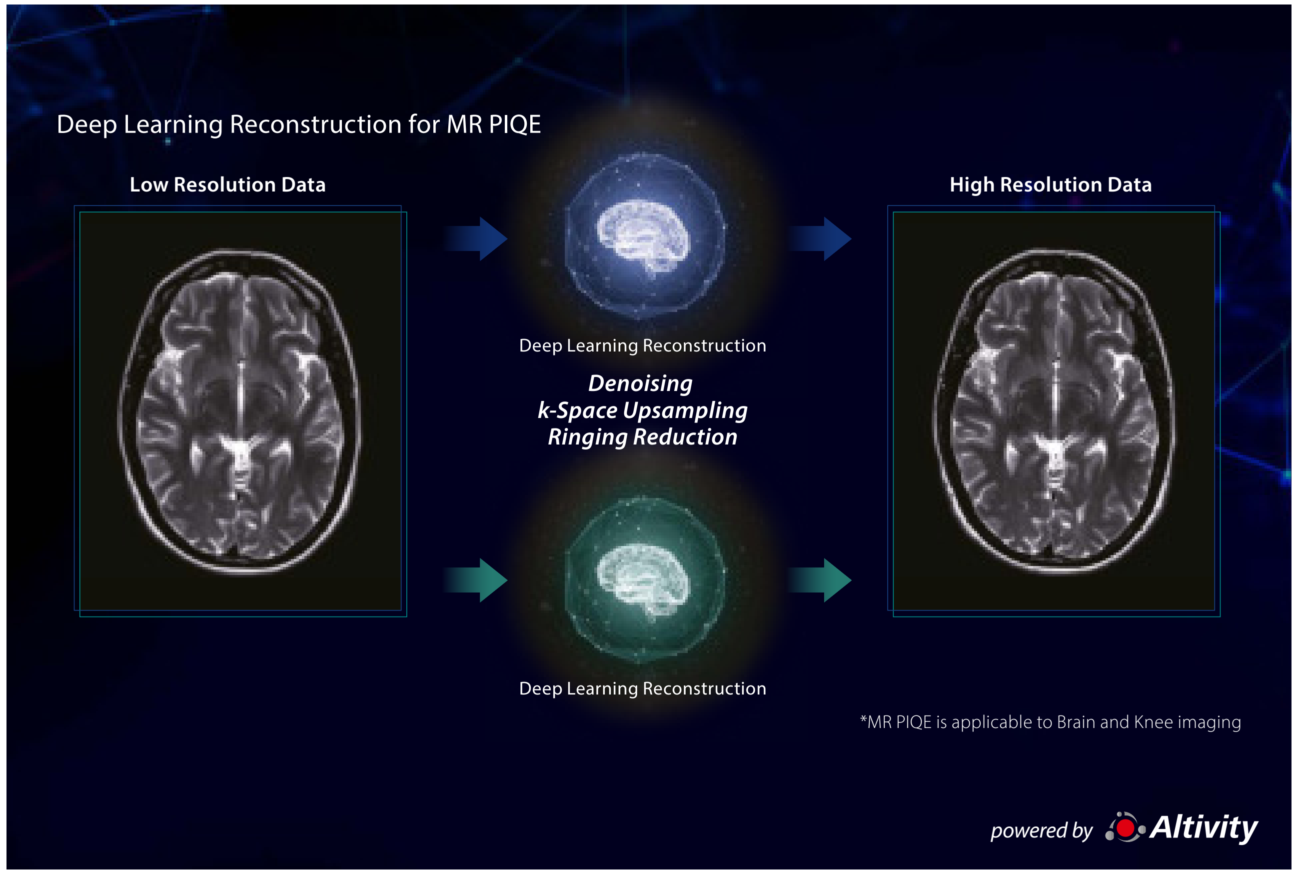
Precise IQ Engine (PIQE) for MRI

Valentin H. Prevost, Ph.D.

In magnetic resonance imaging, image sharpness is one of the main criteria to allow delineation of fine structures that are important for clinical diagnosis. One way to improve the sharpness is to increase the acquired matrix size, but this is generally associated with a lower signal to noise ratio (SNR) or a longer scan time. Historically, some methods have been proposed to artificially increase the reconstructed matrix size, but this often leads to additional Gibbs ringing artifacts immediately adjacent to high-contrast interfaces. Following the strong success of its Deep Learning-based denoising solution (Advanced intelligent Clear-IQ Engine: AiCE), Canon has recently introduced Precise IQ Engine (PIQE), a solution that enables increased resolution reconstructions. With the use of multiple Deep Learning algorithms, PIQE reduces noise from the images, increases the matrix size, and can potentially remove any Gibbs ringing artifacts.



PIQE can then triple the in-plane matrix size leading to a higher image sharpness, while maintaining a high SNR, and without altering the image quality. PIQE can be used at both 1.5 and 3T, without requiring acquisition adjustments, and can benefit several scenarios, such as imaging small structures or even fast imaging when patient status requires.

Two leading radiology experts involved in the product evaluation of PIQE share their feedback.

The first is Dr. Benoit Sauer, a Radiologist and the General Director of MIM (Medical Imaging) Group (based in Strasbourg, in France).

"Super Resolution means gaining spatial resolution with the same SNR and less artifacts (e.g. Gibbs ringing). This is especially needed in small structures, like ear, cartilage, or coronary artery, to propose a better diagnosis. PIQE is a promising solution that fits perfectly with these specifications."

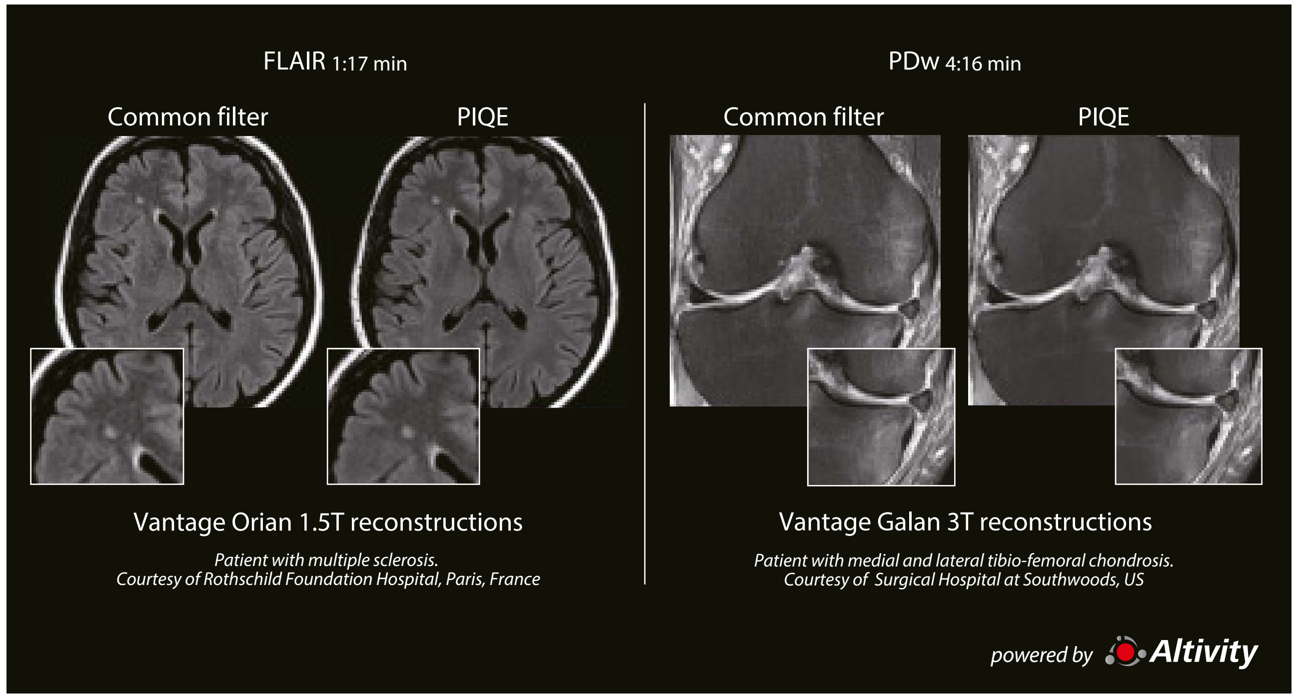
Dr. Benoit Sauer
Radiologist and General Director of MIM (Medical Imaging) Group (based in Strasbourg, France).

Could you comment on the value of PIQE from your recent experience?
"One of the big challenges with MRI is to achieve high image quality in a limited time. Historically, the MR community and companies focused their improvements on the optimization of sequences, but in my opinion, working on image reconstruction is the new trend to follow! AiCE has 'paved the way' forwards for Deep Learning Reconstructions (DLR), and PIQE is the next step. We tested it in our two Canon 1.5T systems and we observed important image quality improvements, both in terms of SNR and sharpness."

Would you consider using PIQE on all your patients?
"Yes, but in different ways. In our clinical practice, we have several different types of protocols, depending on patient status and indications, and PIQE has been found useful in all of these cases. For example, in MSK imaging, gaining spatial resolution with the same scan time is what I'm looking for, especially for the evaluation of cartilage lesions or meniscal tears. For brain imaging in elderly or patients with severe comorbidities, we created faster protocols to be combined with PIQE that save precious scan time and avoid motion artifacts. Our philosophy is to offer personalized care and answer the clinical question, while maintaining optimal patient comfort."

What does the term 'Super Resolution' mean to you, and could it impact your clinical activity?
"Super Resolution means gaining spatial resolution with the same SNR and less artifacts (e.g. Gibbs ringing). This is especially needed in small structures, like ear, cartilage, or coronary artery, to propose a better diagnosis. PIQE is a promising solution that fits perfectly with these specifications.

A second expert involved in this evaluation was Dr. Daniel Chow,



Co-Director of the Center for Artificial Intelligence in Diagnostic Medicine and Assistant Professor-in-Residence at the Department of Radiological Sciences at the University of California, Irvine, USA.

What is your opinion on artificial intelligence and its place in medical imaging?

"Artificial intelligence has the potential to improve equity. 3T systems are generally more expensive and have a smaller bore size. Getting higher resolution images with 1.5T, while also gaining a larger bore size AND going faster have the potential to help us reach more patients."

What were your thoughts when you reviewed the PIQE images?

"I initially thought the 1.5T images reconstructed with PIQE were generated from a 3T scanner, and I am very impressed by how far advances in PIQE technology has matured! PIQE clearly improved spatial resolution, which can make spotting things like metastasis or subtle lesions easier." //

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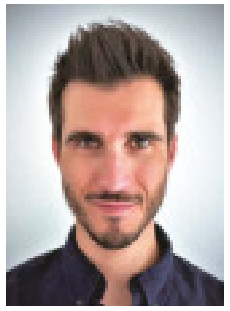

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DWI-FLAIR in the Management of Wake-up Stroke

Natalja Kulagina, Ph.D.

To date, fluid-attenuated inversion recovery (FLAIR) magnetic resonance imaging (MRI) in tandem with diffusion MRI is the most promising imaging marker for the estimation of stroke onset, which is crucial in wake-up stroke (WUS) patients. However, visual/manual evaluation is time-inefficient and prone to inter and intra-rater agreement variability, which is a paramount limiting factor. This section presents a succinct and non-exhaustive review of DWI-FLAIR in the context of WUS imaging and post-processing approaches.

Stroke, a life-threatening medical condition characterized by a sudden neurological deficit, has been occurring in humans for millennia. Although the underlying incidents were poorly understood, the first case of stroke was described as apoplexy by Hippocrates more than 2,400 years ago[1]. In the 1600's, Dr. Jacob Wepfer discovered that apoplexy was caused by the alteration of cerebral blood flow (CBF) and induced either by an intracerebral hemorrhage, or an occlusion of brain blood supply vessels. Later in the mid-nineteenth century, Rudolf Virchow employed the terms hemorrhagic (sanguinea) and ischemic, which are currently applied to designate a hemorrhagic or an ischemic stroke. Downstream, the relationship between time and the consequences of cerebral ischemic injury incited the widely used expression "Time is brain", which was quantified in 2006 as a loss of nearly 2 million neurons each minute[2]. While 62% of all strokes are ischemic (approximately half of them are caused by Large Vessel Occlusion (LVO)), hemorrhagic strokes are associated with high morbidity and mortality of over 50%. Globally, stroke is the second cause of death (6.6 million deaths in 2019) and the third cause of disability worldwide, with the highest burden in low and middle-income countries[3,4]. Although stroke is mainly associated with older populations, 20% of strokes occur in patients under 50 years old and one in four strokes is recurrent, which highlights the role of primary and secondary prevention. Indeed, hypertension represents the most prevailing risk factor (56%), followed by poor diet (31%) and high Body Mass Index (BMI, 24%), all of which are part of manageable risks[3-5].

Currently, the diagnosis of stroke relies on neuroimaging, which is essential in stroke evaluation and therapy selection. Indeed, given the importance of cerebral vascular and tissular state rather than factually the time, the perception of stroke over the past years progressively transitioned from "Time is brain" to "Imaging is brain"[6]. In parallel, before the 1990s the treatment of acute ischemic stroke (AIS) principally targeted symptoms and rehabilitation. The first breakthrough arrived in 1995 with the approval of intravenous tissue plasminogen activator (IV-tPA, alteplase) for intravenous thrombolysis (IVT)[5]. It was demonstrated as an efficient and safe blood clot-lysing medication when administrated within a 3-hour time of symptom onset (further protracted up to 4.5 hours). Indeed, in mild but disabling strokes time progressively diminishes the benefit of alteplase and increases the risk of fatal hemorrhagic transformation[4,5]. Later in 2015, the emergence of endovascular thrombectomy (EVT) transformed stroke clinical workflow worldwide, which led to a graduated extension of treatment time window up to 24 h due to DEFUSE 3 and DAWN randomized clinical trials[6]. Specifically, both trials assessed thrombectomy in patients with the time of symptom onset beyond 6 h (6-16 h in DEFUSE 3 and 6-24 h in DAWN) guided by advanced imaging, and demonstrated an improved functional outcome at 90 days[6-8]. Subsequently in 2018, the established inclusion criteria were incorporated into international guidelines for the early management of AIS (e.g.,[9]) and hospital workflow. Although this advancement revolutionized the routine of stroke treatment, it did not concern patients that may be eligible for IVT, such as WUS with unknown time of symptom onset.

Wake-up stroke (WUS) imaging

WUS occurring during sleep accounts for 14% - 25% of AIS and is characterized by the absence of symptoms prior to falling asleep and, therefore, the unknown time of symptom onset. In general, WUS would not qualify for IVT, but it has been estimated that the risk of stroke increases in morning hours, particularly between 6 AM and 9 AM. This observation suggested that a fraction of WUS patients might be eligible for IVT[10-12]. The benefit of alteplase is time-dependent and AIS patients within 4.5 h of stroke onset eligible for IVT (e.g., ≥ 18 years old, no intracerebral hemorrhage, suspected disabling stroke) are treated immediately after exclusion of hemorrhagic stroke and stroke mimics[9]. Thus, given the central role of time in the management of stroke, a number of studies have been investigating neuroimaging methods to estimate the time of stroke onset[13-20]. Indeed, it is well known that restricted CBF results in cytotoxic edema within minutes due to intracellular water accumulation from damaged cells[21,22], which modifies the diffusion of water and can be detected in diffusion-weighted imaging (DWI) via hyperintense signal on b1000 series and reduced apparent diffusion coefficient (ADC)[23]. Although DWI and ADC were found to be more efficient than T2-weighted imaging in early stroke detection[18], already in 1995 T2 imaging showed potential for temporal characterization of ischemia due to signal increase over time in rats[14], which was further refined to a time course (Figure 1). However, the inability of T2-weighted imaging to distinguish between cerebrospinal fluid (CSF) and ischemic lesion placed FLAIR sequence in the spotlight. Specifically, in addition to higher accuracy in stroke detection within 6 h, FLAIR is less prone to artifacts given the reduced signal from CSF and was reported to show 70 % of images more explicitly than T2[17].

Subsequently, several preliminary studies exploited the use of FLAIR in tandem with DWI as an appraisal marker for stroke lesions within 6 h[27]. For instance, it was determined that positive DWI and negative FLAIR were likely to indicate the occurrence of ischemic stroke within 3 h or less with a specificity of 0.93 and a positive predictive value of 0.94[16]. Another study explored the DWI-FLAIR mismatch to identify patients within 4.5 h and exhibited a specificity of 0.78 and a positive predictive value of 0.83[15]. Therefore, a hyperintense DWI signal and a normal FLAIR signal were defined as positive DWI and negative FLAIR (DWI+/FLAIR- or DWI-FLAIR mismatch) (Figure 2), further associated with the 4.5 h-time window of stroke onset showing 0.62-0.66 sensitivity and 0.70-0.78 specificity[27].

Substantially, in 2018 the WAKE-UP randomized clinical trial demonstrated a significantly improved functional outcome at 90 days in WUS patients selected via DWI+/FLAIR- and treated with alteplase, compared to the placebo group[20]. Although the number of deaths and symptomatic intracranial hemorrhages were higher in the alteplase group, this increase was not significant. Consequently, the current guidelines recommend alteplase administration in the case of WUS and DWI+/FLAIR-, and in absence of contraindications[9], which was reported successful in a single-center experience[29]. In addition, a recent meta-analysis of four clinical trials, including WAKE-UP, THAWS and ENCASS-4 that used DWI-FLAIR qualitative mismatch (DWI+/FLAIR-) as one of their inclusion criteria for IVT, confirmed to a greater extent the favorable functional outcome at 90 days post-stroke[30].

Limitations

In the WAKE-UP trial patients with infarction volume less than one-third of the middle cerebral artery area and not presenting hemorrhage were further selected based on the visual assessment of DWI/FLAIR images. However, visual evaluation of FLAIR is subjective, and the inter-rater agreement was shown to be moderate implying misclassification. For instance, the rating of imaging data set of 143 patients (the sample of PRE-FLAIR study) by eight raters for inclusion according to WAKE-UP trial inclusion criteria resulted in junior inter-rater agreement of 73% and senior inter-rater agreement of 75%[31]. In addition, the semi-quantitative hot spot rating method (Figure 3) was manually applied by five raters to a subset of 50 patient data, which consists of determining signal intensity (SI) of the ischemic lesion relative to the contralateral healthy region relative Signal Intensity (rSI). Although the rSI threshold of 1.20 was suggested for FLAIR+, it did not outperform visual assessment in terms of inter-rater agreement[31]. Thus, given that visual evaluation depends on numerous factors, such as rater experience, image quality and signal subtility, several automated quantification methods have been developing[32-37].

Indeed, multiple Machine Learning (ML) approaches (with or without deep features) were evaluated for stroke temporal classification (</≥ 4.5 h) demonstrating variable sensitivity. For example, three ML models (logistic regression (LR), support vector machine (SVM) and random forest (RF)) were

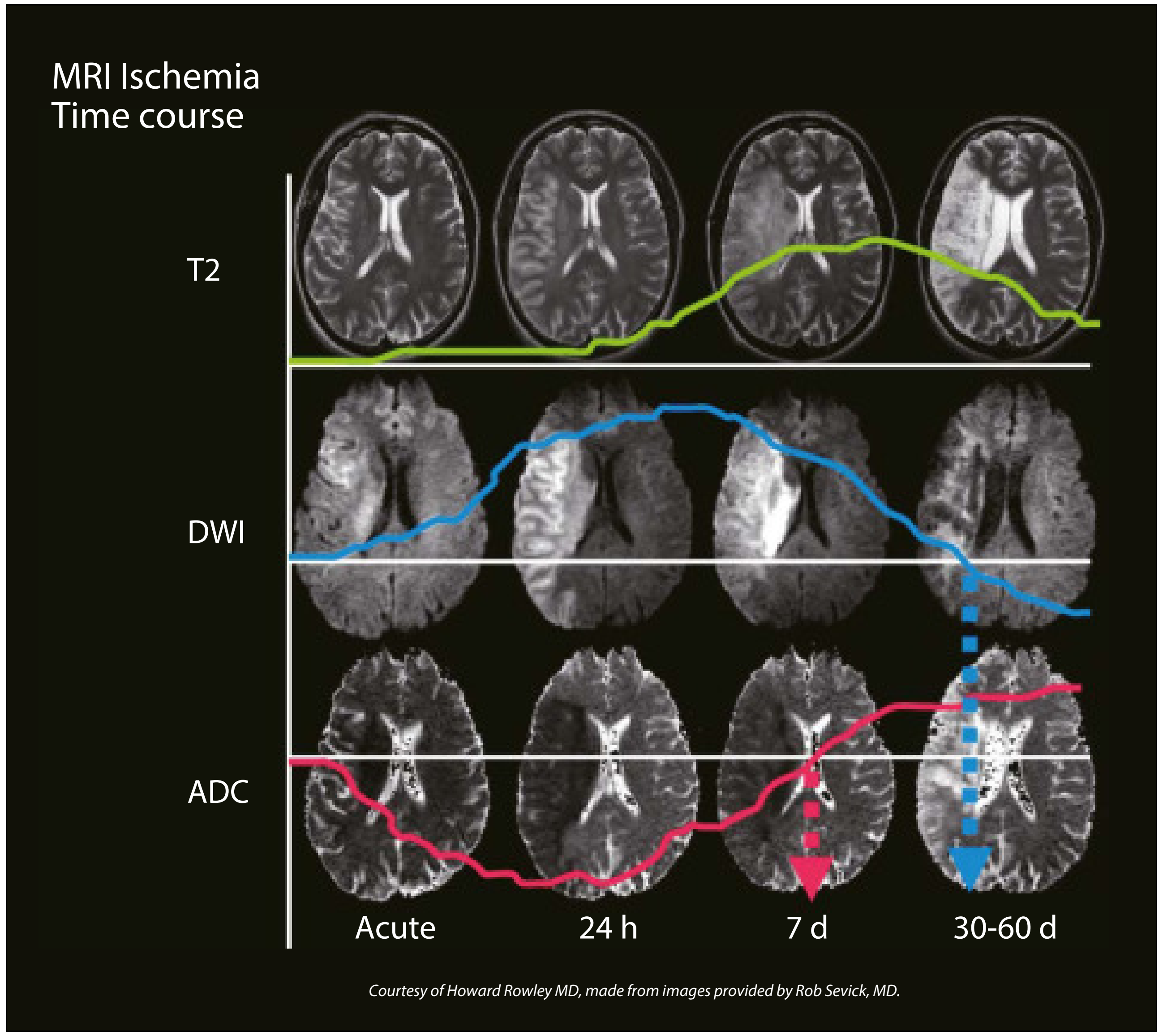

Figure 1: MRI ischemia time course. Diffusion (DWI) turns positive within minutes of ischemia onset, along with its derived apparent diffusion coefficient (ADC)[23,24]. T2-weighted images start to turn positive approximately 4-5 hours after stroke onset[17,24]. Colored lines show schematic representation of the time courses compared to baseline, with ADC evolving the fastest and becoming isointense at about a week[25]. DWI may remain relatively bright for up to a month while T2 will remain hyperintense for a longer period[24,26].

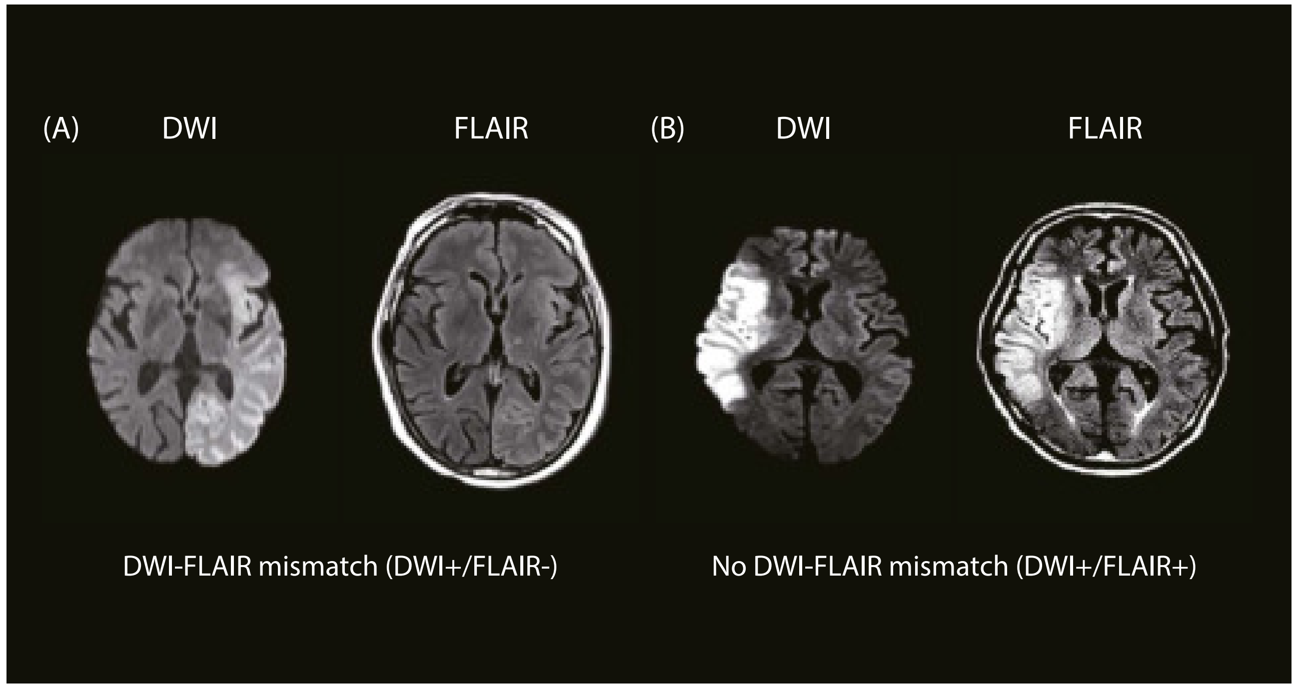

Figure 2: Examples of DWI-FLAIR intensities. (A) DWI-FLAIR mismatch (DWI+/FLAIR-): hyperintensity is present on DWI but not on FLAIR. (B) No DWI-FLAIR mismatch (DWI+/FLAIR+): hyperintensity is present on both DWI and FLAIR. DWI: diffusion-weighted imaging, FLAIR: fluid-attenuated inversion recovery. Adapted from [28].

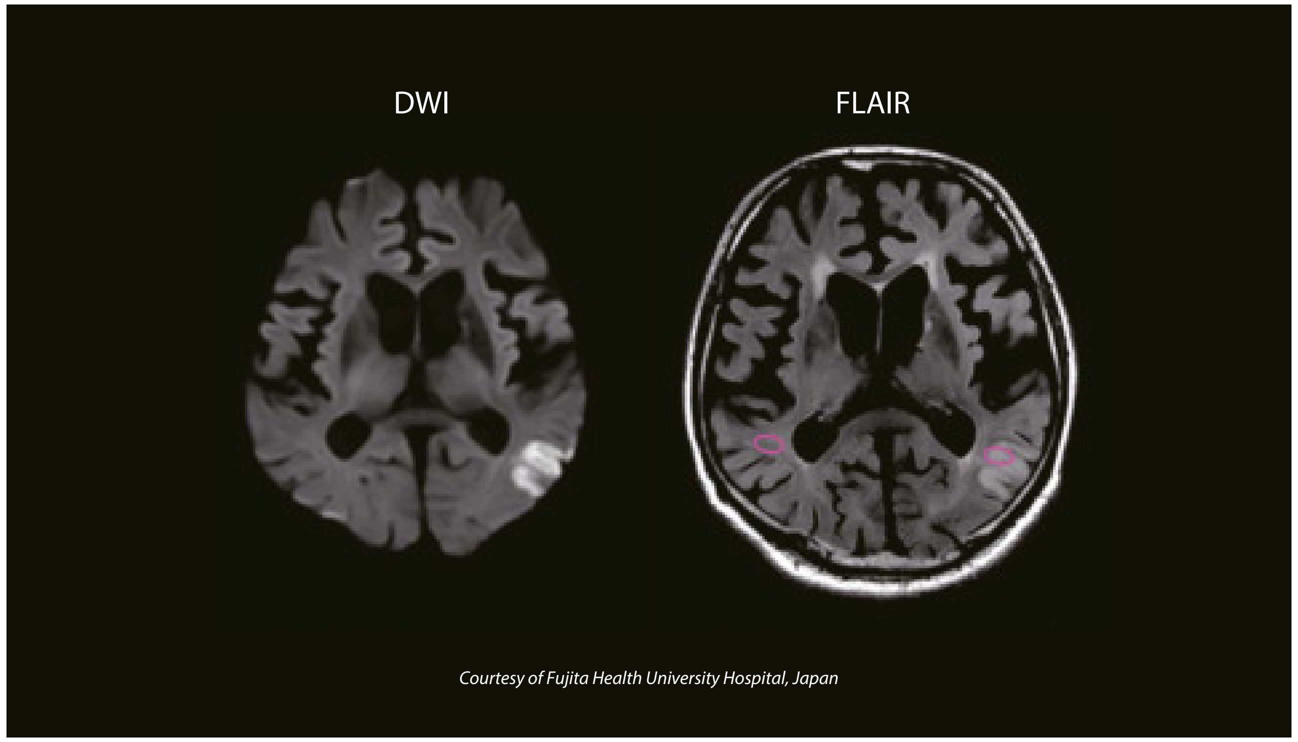

Figure 3: The hot spot method. This method consists of visual identification of an area on fluid-attenuated inversion recovery (FLAIR) images that corresponds to the acute ischemic lesion on diffusion-weighted imaging (DWI) images. Downstream, a small region of interest (ROI) is positioned on FLAIR within the region of highest signal intensity (SI). This ROI is further mirrored to the contralateral hemisphere followed by the calculation of the ratio between the FLAIR of interest SI and the reference FLAIR SI. Adapted from[31].

assessed in comparison to visual evaluation and showed higher sensitivity (0.73-0.76 for ML methods vs 0.49 for visual rating) and comparable specificity (0.826 vs 0.913)[32]. Similarly, the ML voting of five classifiers (LR, SVM, RF, gradient booster decision tree (GBDT) and extra trees (ET)) achieved a sensitivity of 0.769 and a specificity of 0.840[33]. Another study reported ML radial basis function kernel (svmRadial) as the most stable and the best-performing method with an accuracy of 0.825, sensitivity of 0.823, specificity of 0.827 and area under curve (AUC) of 0.895[34]. However, it was pointed out that lower specificity of ML methods might trigger an increase in false positive rate and a higher risk of hemorrhagic transformation, which highlights the necessity of further investigation[32].

FLAIR relative Signal Intensity

The threshold of FLAIR rSI was refined and suggested as <1.07[38] and <1.06 for predicting the time of stroke onset ≤4.5 h[39]. In addition, rSI ≤1.18 demonstrated a sensitivity of 0.86 and a specificity of 0.79 in patient identification within 6 h, while rSI ≤1.2 showed a sensitivity of 0.89 and a specificity of 0.76 within the 8 h-time window[40]. Moreover, the increasing FLAIR rSI displayed a negative relationship with the benefit of IVT, which correlates with the time-dependent nature of stroke treatment[39]. Hence, although it is unclear whether rSI significantly improves the diagnosis, its potential value is undoubtable (combined with other clinical/imaging data), particularly in the context of ambiguous FLAIR signal intensity. Indeed, at present DWI-FLAIR mismatch and potentially rSI remain the most promising imaging markers for the temporal estimation of stroke occurrence. Another point to take into consideration is the time-inefficiency of rSI manual quantification, which requires a fully automated solution, to date not existing on the market.

Automation Platform MR DWI / FLAIR Measurement*

The developed solution Automation Platform MR DWI / FLAIR Measurement is fully automated and performs FLAIR quantification via FLAIR rSI. Concisely, the ischemic region of interest (ROI) is first segmented in the DWI sequence according to decreased ADC, which is restrained to a single hemisphere to reduce false positive rate. Patient FLAIR data is further co-registered with the corresponding DWI sequence where the ischemic ROI is projected onto FLAIR sequence thus enabling the analysis of FLAIR signal inside the lesion. In line, the reference area is automatically segmented in the contralateral hemisphere as the contralesional mirror region according to the brain midplane. Subsequently, the reference FLAIR value µFLAIR is computed as the median FLAIR signal inside the segmented unimpaired area, while the relative FLAIR intensity in the ischemic ROI is calculated as the ratio of FLAIR intensity of interest to the reference FLAIR intensity:

$$\text{FLAIR r} = \frac{\text{FLAIR}}{\mu\ \text{FLAIR}}$$

Consequently, the map of ischemic region FLAIR rSI is generated within seconds and overlayed with FLAIR, and the calculated FLAIR rSI is displayed (Figure 4). In Figure 4, the patient presents hyperintense DWI along with decreased ADC and positive FLAIR with rSI = 1.2, which indicates that the time of stroke onset is likely to be > 4.5 h.

** Not available in all geographies.*

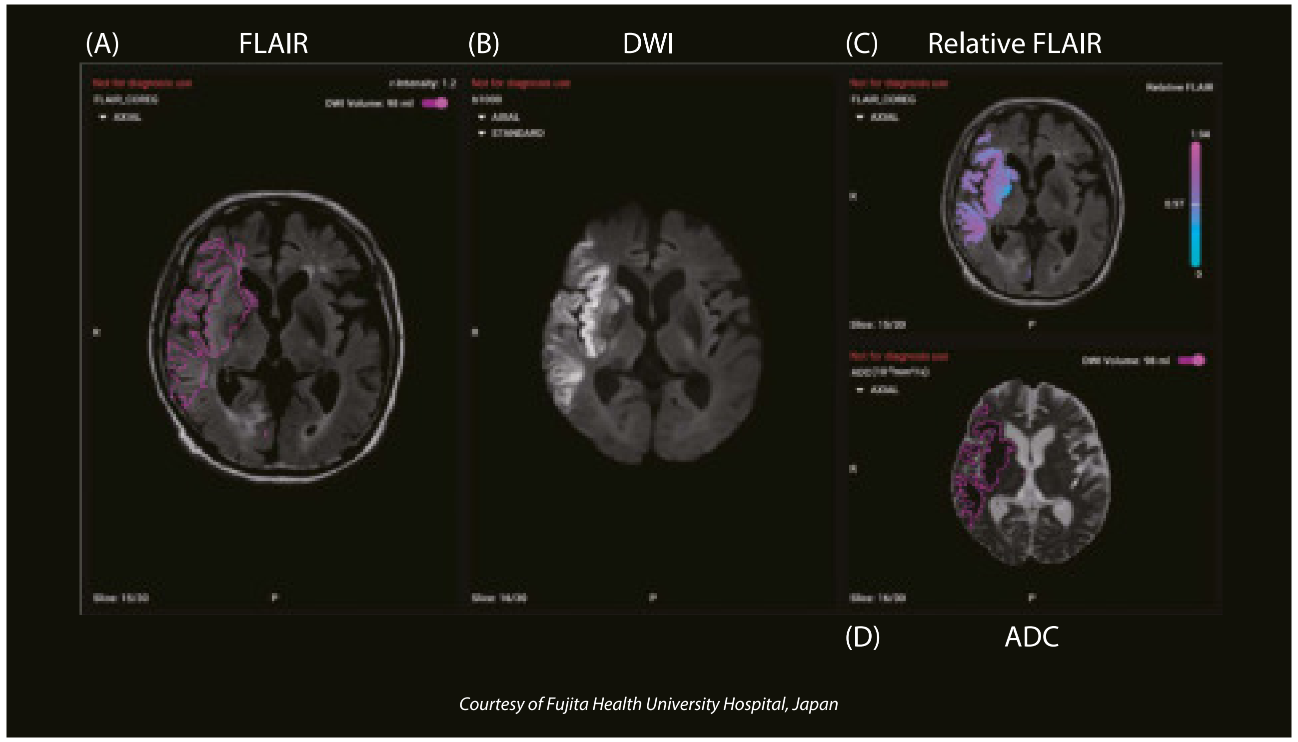

Figure 4: Automation Platform MR DWI / FLAIR Measurement lesion quantification. (A) Apparent diffusion coefficient (ADC) hypointense volume (pink line) on fluid-attenuated inversion recovery (FLAIR) sequence. (B) Diffusion-weighted imaging (DWI) b1000 series. (C) Relative FLAIR intensity map (from light blue to purple: 0-1.94) in ADC hypointense volume on FLAIR sequence. (D) ADC. Images were automatically generated by Automation Platform MR DWI / FLAIR Measurement.

Conclusion and future directions

Taken together, DWI-FLAIR mismatch imaging marker is currently the only element that enables the estimation of WUS time window <4.5 h while clinical practice requires automated solutions for a more efficient assessment of DWI-FLAIR data. Indeed, inter and intra-rater variability is a recurrent issue of visual/manual evaluation along with time inefficiency. In parallel, given that automated solutions may exhibit several limitations due to patient motion, brain natural asymmetry and FLAIR hyperintensity caused by other pathologies (frequent in older populations), physicians are always expected to appraise these factors along with additional clinical data. Nevertheless, time efficiency of the automated approach is prominent, which undeniably implies a massive potential in the assistance of WUS management. As mentioned, WUS represents up to 27% of AIS, and visual/manual assessment is prone to misclassification, which further expands the bourgeoning benefit of automation. In addition, artificial intelligence (AI) is increasingly employed, and AI-based tools (e.g., </≥4.5 h classification, time of stroke onset estimation) pinpoint a promising strategy for further development and improvement of Automation Platform MR DWI / FLAIR Measurement. //

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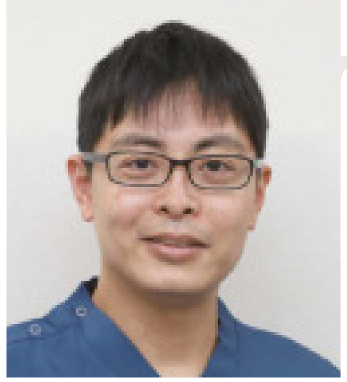
The Broadened Horizons with Higher Image Quality and Higher Acceleration Delivered by Deep Learning Reconstruction on the 1.5T MRI System

Improved examination workflow with AI-based solutions such as Ceiling Camera-assisted positioning based on a Deep Learning algorithm

Shiga General Hospital is a 535-bed core community hospital on the south side of Lake Biwa in Shiga prefecture. Since its opening in 1970, the hospital has provided advanced medical care for patients with cancer, cardiac diseases, and cerebrovascular diseases. In June 2022, the hospital installed a 1.5T MRI system with Deep Learning Reconstruction (DLR), Vantage Fortian manufactured by Canon Medical Systems Corporation. As part of Canon Medical Systems' AI innovation brand Altivity, Vantage Fortian incorporates AI-driven technologies such as Advanced intelligent Clear-IQ Engine (AiCE), which is a DLR technology for adaptive noise reduction in images, and an improved workflow solution employing a Ceiling Camera. We met with Mr. Yusuke Chatani, a radiologic technologist in the Department of Radiology, to discuss the usefulness of Vantage Fortian in routine clinical practice.



> *"It previously took a long scan time even to acquire 3 mm-slice 2D images on the previous system, but AiCE enables to acquire thinner-slice and higher-resolution images without extending the scan time on Vantage Fortian as well as their 3T system."*

Yusuke Chatani, radiologic technologist in charge of MRI
Shiga General Hospital

A wide variety of MRI examinations with emphasis on the head and neck using two MRI systems

Since 2009, Shiga General Hospital has been designated as a Prefectural Cancer Care Hospital. Since 2018, the hospital name has been changed from the former "Shiga Prefectural Medical Center for Adult Diseases" to reflect its expanded mission to provide comprehensive medical care focusing not only on lifestyle-related diseases but also on a variety of other diseases. At Shiga General Hospital, the Department of Radiology is composed of 4 physicians and 31 radiologic technologists for diagnosis and examinations, who are assigned to specific sections according to modality, such as CT and PET. In the MRI section, a radiologist, 3 radiologic technologists and a nurse perform about 32 examinations per day using a 1.5T MRI system Vantage Fortian and a 3T MRI system from another manufacturer. Approximately one-half of the MRI examinations focus on the head and neck, including follow-up examinations for neurovascular diseases and for the detection of brain metastases. The other half include the spine, MRCP and a variety of other examinations. Examinations of all parts of the body are performed for every clinical department and for every diagnostic objective.

The high image quality and outstanding operational flexibility delivered by DLR incorporated in Vantage Fortian

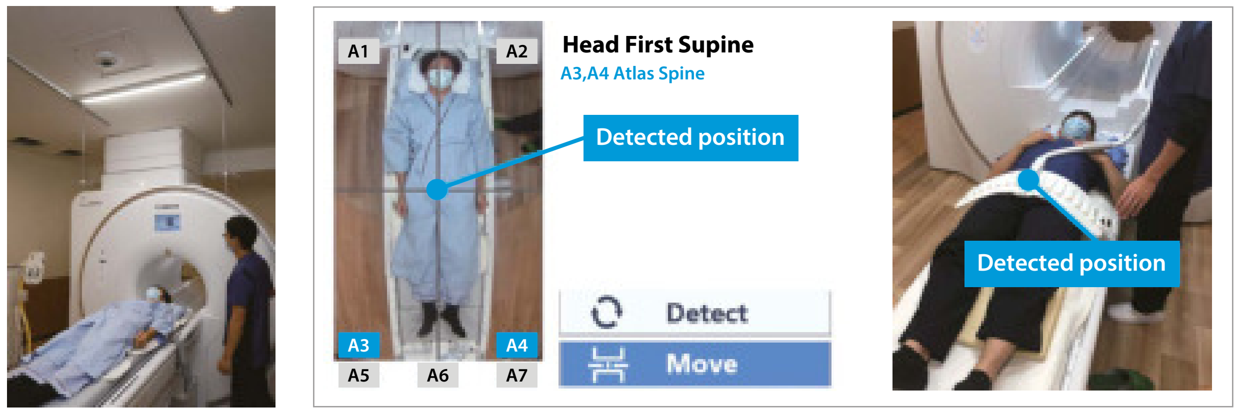
Vantage Fortian was launched by Canon Medical Systems in February 2022 as a 1.5T MRI system with AI-driven technologies to improve image quality and streamline examination workflows. Meanwhile, Shiga General Hospital was planning to replace their previous 1.5T system from another manufacturer. Mr. Chatani explains that the most important criteria to select a new MRI system was image quality. At that time, DLR technologies for MRI were being launched by several different manufacturers. Therefore, the hospital focused on MRI systems with DLR, having expectations for higher-resolution or higher-acceleration imaging. The candidates for new MRI system were narrowed down to three systems, including one from Canon Medical Systems. After arranging several site visits to see the actual systems, Vantage Fortian was ultimately decided on. Mr. Chatani is impressed that Advanced intelligent Clear-IQ Engine (AiCE), which is one of the DLR technologies from Canon Medical Systems, can be flexibly applied to almost all the pulse sequences for 2D and 3D acquisition on Vantage Fortian. He also thinks highly of the system because AiCE allows the retrospective reconstruction for previously acquired images.
AiCE is a DLR technology for adaptive noise reduction in images, which enables the ability to extract and remove more selectively noise components from the signal compared with conventional denoising methods, e.g., smoothing filters. The noise reduction level can be selected in five levels and adjusted to achieve the desirable image quality even after acquisition. Mr. Chatani notes that it was easy to adjust image quality based on advice from radiologists soon after the replacement with Vantage Fortian, because the noise reduction level can be retrospectively adjusted without additional acquisition to achieve the desirable image quality. He also adds that most of the hospital's protocols for Vantage Fortian have already been fully optimized, thanks to the flexibility of AiCE.

The broadened horizons in combination with AiCE utilizing various acceleration techniques

There are two different methods with AiCE to benefit from the adaptive noise reduction: one is for high-resolution imaging without extending the scan time, the other is for high-acceleration imaging maintaining the image quality. In terms of the former, AiCE allows to acquire 1 mm-slice 2D images for examinations of the small extremities such as the finger and the wrist joints. According to Mr. Chatani, it previously took a long scan time even to acquire 3 mm-slice 2D images on the previous system, but AiCE enables to acquire thinner-slice and higher-resolution images without extending the scan time on Vantage Fortian as well as their 3T system. In contrast, for spine examinations, the highly-accelerated protocols are adopted maintaining the same spatial resolution as the previous. Mr. Chatani says that when sagittal T1- and T2-weighted images and axial T2-weighted images are acquired in the spine examinations, AiCE reduces the total scan time by more than 5 minutes on Vantage Fortian compared with the previous system. Nevertheless, the image quality is comparable to that acquired on their 3T system. He notes that AiCE greatly broadens the options for higher image quality or higher acceleration in MRI examinations depending on the situation.
Furthermore, Fast 3D mode, which is one of the acceleration techniques for 3D acquisition, has been used to accelerate head MRA in combination with AiCE. The combination allows to acquire higher-resolution MRA images without extending the scan time and improves the depiction of vascular structures, Mr. Chatani also says that the combined use of AiCE and Fast 3D mode permits to acquire high-resolution MRA images on Vantage Fortian in almost the same scan time as on their 3T system. Due to inflow effects in MRA, there are generally differences of the depiction of vascular lesions, e.g., microaneurysms and vascular stenosis, between 1.5T and 3T systems. Hence, their 3T system would often be employed in these cases. However, Vantage Fortian has recently compensated for their 3T system in the examinations for those cases. Dr. Yusaku Moribata, Head of the Department of Diagnostic Radiology, observes that Vantage Fortian provides improved overall image quality. Especially in head MRA, it allows blood vessels to be clearly depicted and the morphological characteristics of aneurysms to be precisely evaluated. In addition to head MRA, neck MRA is often requested by the Department of Neurosurgery. Large FOV images for neck MRA are usually required including the upper section of the aortic arch, but the combination of AiCE and Fast 3D mode enables to acquire them in a short scan time of about 2 minutes. Other than Fast 3D mode, Vantage Fortian incorporates a variety of acceleration techniques such as Compressed SPEEDER, all of which can be used in combination with AiCE. Mr. Chatani observes that as an added value of AiCE, the combination with various acceleration techniques reduces the scan time while maintaining the image quality, and that results in minimizing motion artifacts generated by uterine peristalsis in gynecological examinations. Mr. Chatani is amazed by the fact that AiCE allows to perform routine gynecological examinations without using radial sampling to correct body motion artifacts, which typically affects overall image contrast unlike Cartesian sampling.

Patient positioning using the Ceiling Camera

Vantage Fortian incorporates a variety of features to streamline its examination workflow, including Ceiling Camera-assisted positioning solution, in which a camera manufactured by Canon on the ceiling of the scan room detects the target position and moves the patient table into the magnetic center. The Intelligent Monitor on the gantry shows the patient on the table, and the operator can perform coil set-up while referring to the guidelines indicating the detected target position. At Shiga General Hospital, the Ceiling Camera-assisted positioning has been the most useful for the prostate examinations with the 16ch Flex SPEEDER coil, whose high-density element design makes it possible to acquire high-SNR images with localized coil sensitivity. However, the coil is so small that even if there is a slight error between a targeted position and a landmarked



The Ceiling Camera automatically detects the target position.

The operator sets the 16ch Flex SPEEDER according to the guidelines indicating the detected position displayed on the Intelligent Monitor. (The above figures show a prostate examination as an example.)

powered by Altivity

Patient positioning using the Ceiling Camera

“Before using the Ceiling Camera, the patient positioning in case of prostate examinations would often vary slightly depending on the operator’s experience and the patient’s physical characteristics. That results in more accurate and consistent positioning in prostate examinations.”

Yusuke Chatani, radiologic technologist in charge of MRI
Shiga General Hospital

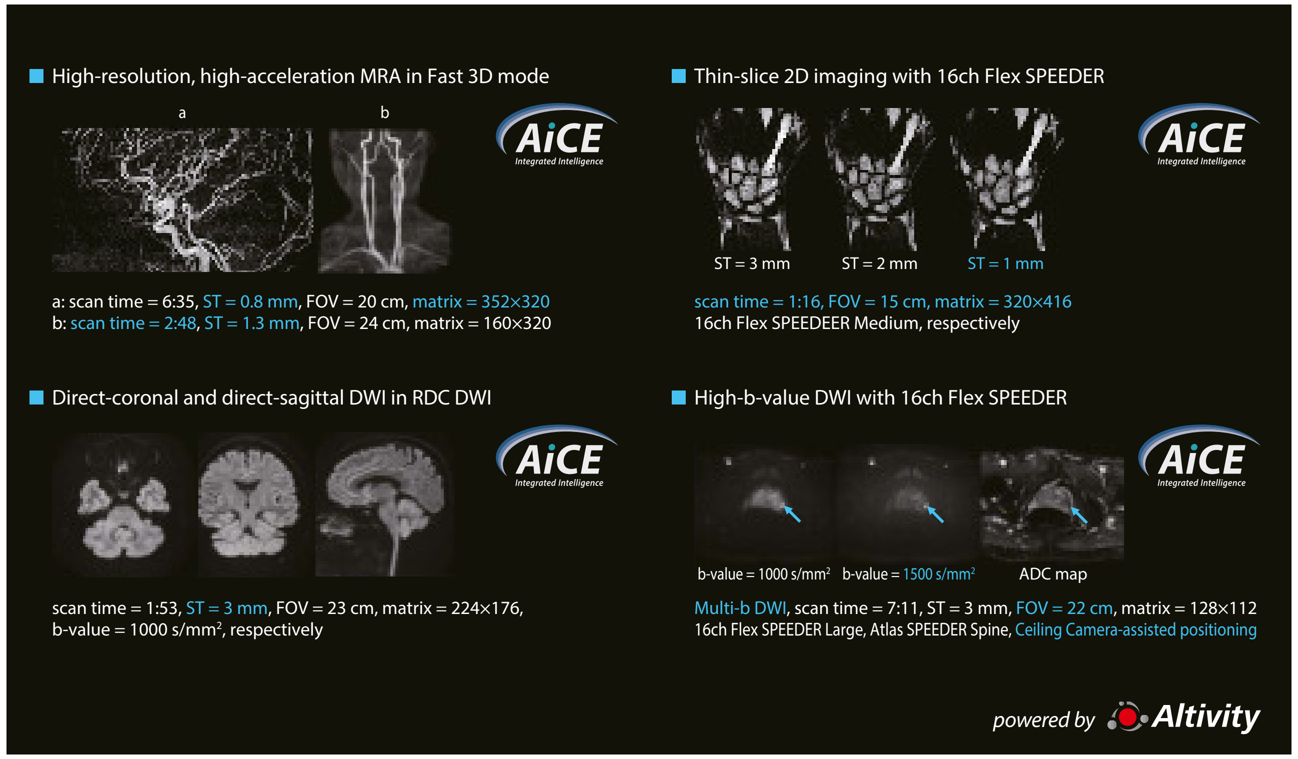
position with laser marking, it could lead to the target deviating from the region covered with the localized coil sensitivity during examinations for small anatomies such as the prostate. Before using the Ceiling Camera, the patient positioning in case of prostate examinations would often vary slightly depending on the operator’s experience and the patient’s physical characteristics. However, recently, it has been easier to perform the patient positioning and coil set-up with the Ceiling Camera, because the 16ch Flex SPEEDER coil just has to be set on patients referring to the detected position shown on the Intelligent Monitor. That results in more accurate and consistent positioning in prostate examinations. Mr. Chatani also points out another advantage of the positioning solution. During the ongoing coronavirus pandemic, it is also beneficial to be able to perform the patient positioning while minimizing physical contact. In addition, the positioning solution prevents unnecessary repositioning caused by manual-landmark errors depending on the operator’s experience. Thus, the examination workflow has been streamlined, allowing medical staff to have plenty of time to explain the examinations to patients.

More adaptive examinations for each case with artifact reduction technologies

Vantage Fortian incorporates a variety of unique reconstruction technologies not only for adaptive noise reduction, i.e., AiCE, but also for artifact reduction, which includes those for motion artifact reduction, i.e., Iterative Motion Correction (IMC), and for distortion correction in diffusion-weighted images (DWI). In particular, Reverse encoding Distortion Correction (RDC) DWI minimizes distortion caused by susceptibility effects and eddy currents in DWI. RDC DWI is mostly used for head examinations at their hospital to reduce the distortion of DWI at the base of the brain caused by the presence of air, which enhances susceptibility effects. It is available and useful in all imaging planes, especially in direct acquisition of coronal and sagittal planes for DWI. Thin-slice coronal DWI for head examinations are sometimes requested by the Department of Neurosurgery to evaluate the lesions in the brain stem, where the distortion is likely to be generated in DWI. Mr. Chatani adds that the examinations are performed with greater confidence thanks to RDC DWI, although that was not the case with the previous system. Moreover, mUTE (minimized acoustic noise utilizing UTE) sequences can be used for metal artifact reduction in head MRA, especially in case of the follow-up after coil embolization, allowing to acquire DSA-like 4D MRA images to evaluate hemodynamics without contrast enhancement and radiation exposure as added values. As mentioned above, since Vantage Fortian was introduced in their hospital, it has greatly broadened the horizons and the possibilities for MRI examinations, increasing expectations for clinical utilization. With regard to future prospects, Mr. Chatani states that T1 mapping for cardiac examinations is now being introduced on Vantage Fortian, whereas it cannot be done on their 3T system. AiCE is also available for precise quantitative analysis such as T1 mapping in addition to high resolution and high acceleration. Shiga General Hospital will continue to address complex challenges for higher quality examinations on Vantage Fortian to meet the demands of every clinical department.

The higher-resolution and -accelerated imaging and streamlined examination workflows delivered by Vantage Fortian are expected to lead to even higher reliability and efficiency in MRI examinations. //

(Interview conducted on November 15, 2022)



Clinical images obtained using Vantage Fortian with AiCE

Shiga General Hospital.

This article is a translation of the INNERVISION magazine, Vol.38, No.1, 2023.

Disclaimer: Deep Learning technology is used in the design stage of the image reconstruction processing. The system itself does not have self-learning capabilities.
The contents of this report include the personal opinions of the authors based on their clinical experience and knowledge.

Advanced intelligent Clear-IQ Engine (AiCE) Improves Image Quality and Scan Times

Dr. Keita Satoyoshi
Chief, Department of Radiology,
Samukawa Hospital, Japan

Samukawa Hospital is a 99-bed core hospital with close ties to the local community in Samukawa-machi, Koza-gun, Kanagawa, Japan. The hospital is committed to establishing a robust community healthcare system by creating strong alliances with a range of healthcare facilities in the region. In 2020, Samukawa Hospital replaced its current 1.5T MRI system with a Vantage Orian 1.5T built with Advanced intelligent Clear-IQ Engine (AiCE) technology. AiCE represents the world's first AI-based solution for improving the signal-to-noise ratio (SNR) of medical images, which the hospital is currently using in its routine clinical practice. In this report, radiologists at Samukawa Hospital discuss their experience with AiCE.

AiCE allows us to perform high-resolution scanning in routine MRI examinations

The Vantage Orian that has recently entered operation at our hospital features reconstruction technology known as AiCE in which a Deep Learning approach is used to reduce noise. AiCE is an innovative technology that can significantly improve the SNR of MRI images, while avoiding any loss in image quality or increase in scan times.

In our actual clinical practice, the introduction of Vantage Orian with AiCE has made it possible for us to acquire high-resolution images in routine examinations with short scan times. Previously, it was difficult for us to perform such examinations due to concerns that the SNR would be unacceptably low.

Figure 1 shows high-resolution images of a patient with an injury of the right supraspinatus tendon. As shown in the images on the left, noise levels can be markedly increased when images are acquired at higher resolution. However, as shown in the images on the right, the use of AiCE ensures an acceptable SNR. High-resolution images can more clearly depict the structural details of such injuries, which means that our radiologists can deliver a diagnosis with greater confidence.

We selected Vantage Orian because it provides clearer MRCP images with shorter scan times

The Director of our hospital, Dr. Hiroyuki Narumi, is a gastroenterologist, which means we receive a large number of requests for magnetic resonance cholangiopancreatography (MRCP). The ability to obtain high-quality MRCP images was a key consideration during our MRI system selection process. We chose Vantage Orian because it allows us to perform MRCP very efficiently by employing AiCE, which improves image quality, in combination with Fast 3D mode, which reduces scan times.

Figure 2 shows preoperative and postoperative images of a patient with choledocholithiasis. The MRCP images showed excellent agreement with the findings of endoscopic retrograde cholangiopancreatography (ERCP). Furthermore, the images were obtained in just 1 minute and 7 seconds, considerably less than the standard seven-minute scan time of our old system.

The postoperative MRCP images were also of a remarkably high quality. This was in spite of the fact that even shorter scan times were used because postoperative imaging was only intended to confirm relief of bile duct dilatation. Scanning could also be performed with a breath-hold time of just 21 seconds. Dr. Narumi, who frequently refers patients for MRCP, was very impressed that Vantage Orian could provide such high-quality diagnostic images with low noise levels and short scan times, providing significant benefit to patients.

Cervical spine MRI can be performed with shorter scan times while maintaining high image quality

In addition to the use of AiCE in routine high-resolution imaging as discussed above, AiCE also allows scan times to be shortened while maintaining the same level of image quality. With our previous MRI system, we needed to reduce the spatial resolution or slice thickness in order to compensate for the loss of SNR at short scan times. With Vantage Orian, because AiCE ensures that an acceptable SNR is maintained, we can perform examinations with shorter scan times with no compromise in spatial resolution or slice thickness.

Figure 3 shows a patient with mild cervical spondylosis. Sagittal images were obtained in a short scan time of about 1 minute and 30 seconds. Before installation of Vantage Orian, the scan time for such images was more than 3 minutes. This means that scan times can now be reduced by half.

As shown in the images on the left, noise levels are quite high when images are acquired without AiCE. However, as shown in the images on the right, AiCE allows clear images to be obtained even with short scan times. It is often difficult for patients with cervical spine problems to remain still for a prolonged period, so the ability to perform routine examinations with such short scan times is a great benefit for our patients.

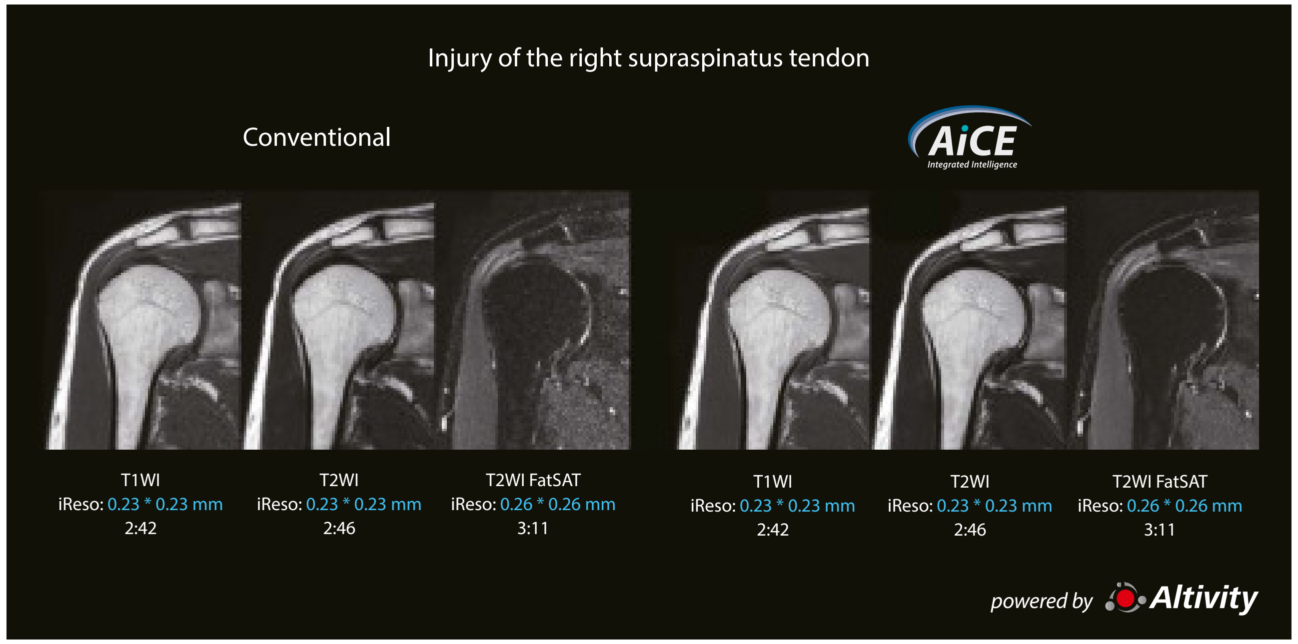


Figure 1

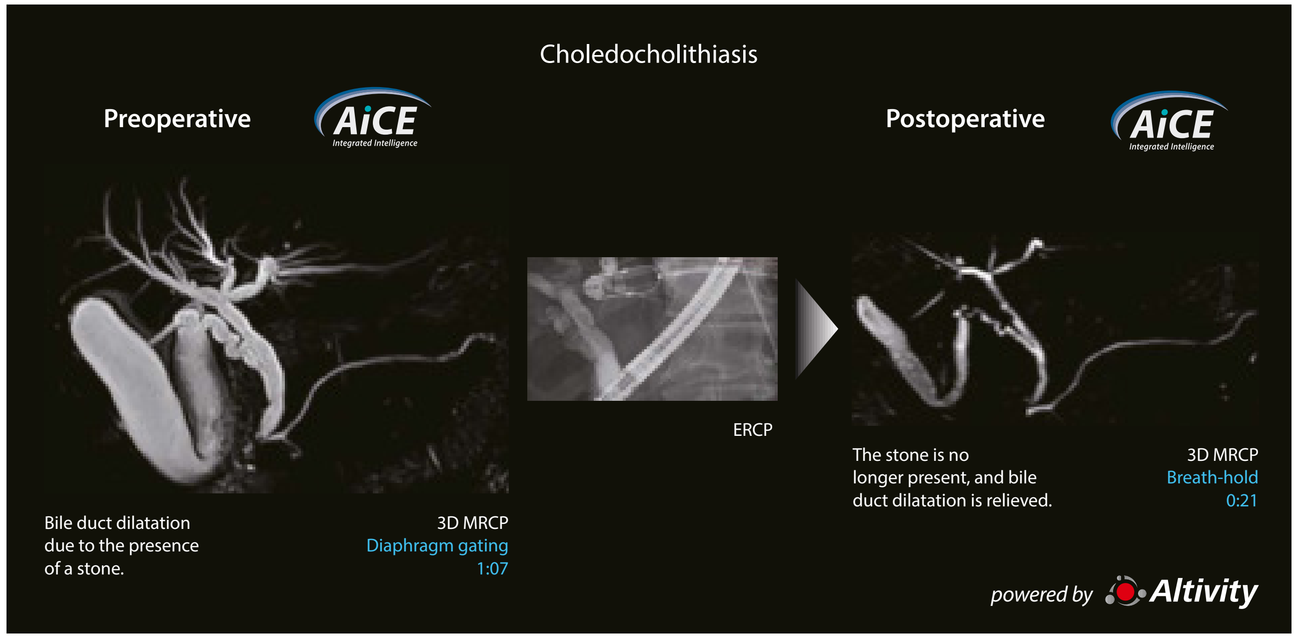


Figure 2

Scan times for routine head studies can be halved

AiCE enables us to employ short scan times as standard practice in routine head studies. Before installation of our Vantage Orian system, the time required for such studies was around 18 minutes. However, after installation, the time required has been halved to about 9 minutes. Images with a higher SNR can be obtained with almost no loss of spatial resolution, even with short scan times. We think this is a testament to the effectiveness of AiCE.

Figure 4 shows images of a patient with acute-phase stroke in the right putamen. Each of the 2D contrast-enhanced images was obtained in a short scan time. The MRA image was obtained at high resolution with a little longer scan time. High signal intensity in the putamen is observed in the T2WI, fluid-attenuated inversion recovery (FLAIR), and DWI images, indicating acute-phase stroke. The total scan time in this case was as short as 8 minutes and 54 seconds. We are very satisfied with our Vantage Orian system with AiCE because it improves examination efficiency while maintaining excellent diagnostic performance.

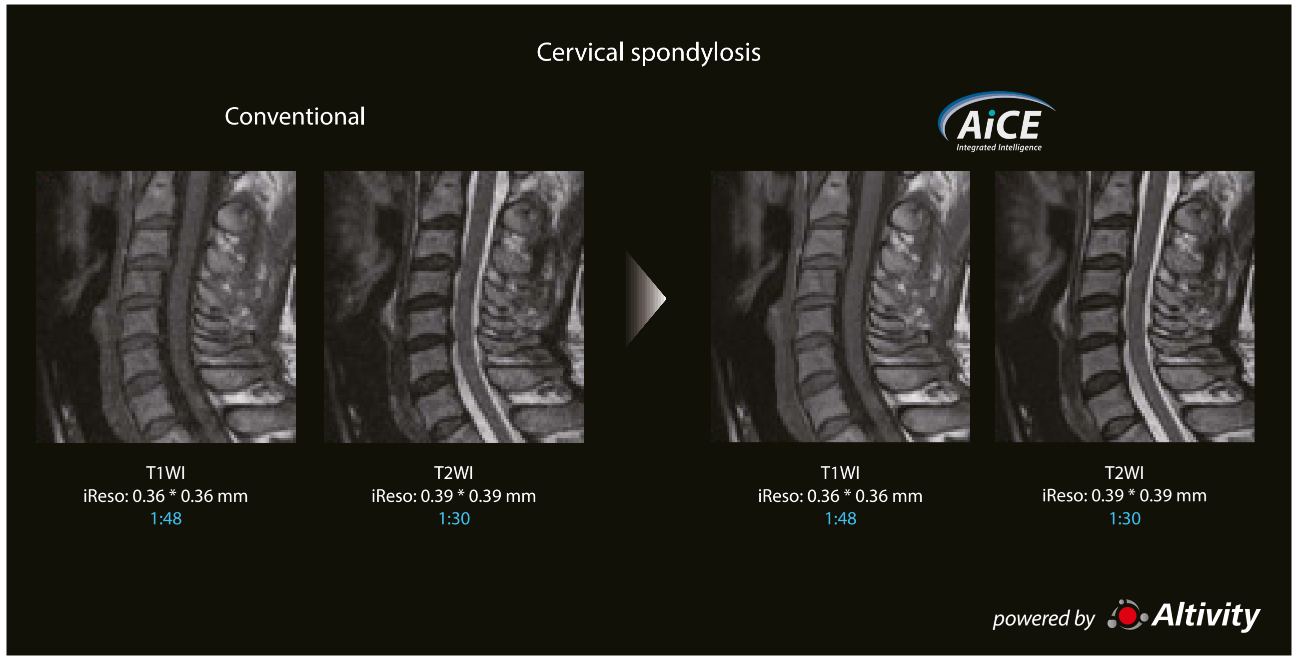


Figure 3

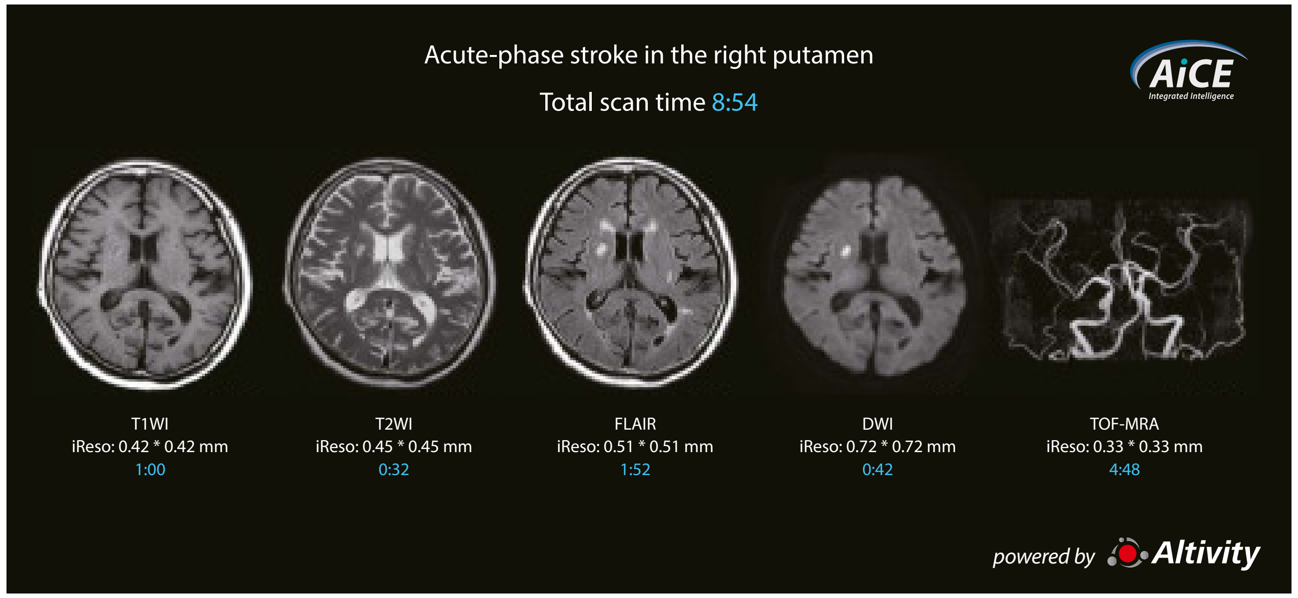


Figure 4

We have very high expectations for the future of AiCE

One of the greatest advantages of AiCE is its wide range of clinical utility. Not only is AiCE useful for examining all regions of the body, it also supports 2D scanning as well as 3D scanning and can be employed in many types of examinations. In the future, we plan to expand the application of AiCE in order to further improve both image quality and examination efficiency.

We are committed to promoting close cooperation between the hospitals in our community, and we actively accept examination referrals from other healthcare facilities in the area. Our new Vantage Orian system has also made it easier for us to manage our examination scheduling, resulting in improved efficiency. We now enjoy greater flexibility in accepting urgent unscheduled examinations, and we expect this to further strengthen our regional healthcare alliance. //

New Normal with AI Deep Learning Reconstruction in MRI in a "With-COVID-19" Era: Uncovering its True Clinical Value

Masato Uno
Chief of Radiological Technologist, Department of Radiology,
Nishijin Hospital, Japan

Nishijin Hospital is a regional referral hospital located in Kamigyoku, Kyoto-shi, Kyoto that serves its local community with a wide range of health and welfare services, including general surgery, urology, plastic surgery, internal medicine, and dialysis care. In 2020, the facility installed a brand-new 1.5T Vantage Orian MRI system, incorporating Advanced intelligent Clear-IQ Engine (AiCE) Deep Learning Reconstruction (DLR) technology, to replace their previous system, which was manufactured by another vendor. In this report, radiologists from the facility discuss their experience using AiCE in routine clinical practice.

Why do we need Deep Learning Reconstruction in MRI ?

The trade-off between image quality and scan time is one of the primary issues faced by clinicians when conducting MRI examinations. In general, when we need a higher quality image, we have to accept longer scan times, and when we need shorter scan times, we have to accept a lower quality image. In either case, compromise is unavoidable in conventional MRI examinations. Even when an advanced MRI system with better basic image quality is used, the above trade-off still exists. However, our new Vantage Orian system from Canon Medical Systems has recently made it possible for us to acquire higher quality images in a much shorter scan time. The Vantage Orian system incorporates AiCE, a noise removing reconstruction technology, which is based on DLR. With AiCE, image quality can be substantially improved in postprocessing, making it possible to obtain high-quality images without extending the scan time, as shown in Figure 1A.

The true value of Deep Learning Reconstruction in MRI is becoming clear in the "With-COVID-19" era

Our Vantage Orian system, which entered operation in May 2020, is the first 1.5T MRI system installed with DLR in Kyoto. Because the Kyoto area is one of the hotspots of the novel coronavirus (SARS-CoV-2) pandemic, scrupulous infection control is essential at our busy hospital. In particular, MRI examinations require patients to remain on the couch for a long time in a confined examination area, so the risk of infection cannot be completely eliminated even though meticulous disinfection procedures are followed. When MRI examinations are performed using AiCE, patients can be moved out of the examination area more quickly (Figure 1B), compared to conventional systems, which not only helps to strengthen infection control (Figure 2A), but also provides a sense of security for both patients and medical staff. One of the most outstanding features of our Vantage Orian system is that it has allowed us to markedly improve throughput with no sacrifice in image quality. A part-time radiologist from a nearby university hospital who recently visited our department commented that the overall image quality was remarkably improved, with some images showing outstanding image quality with a signal-to-noise ratio (SNR) comparable to that of 3T MRI images.

In addition to high image quality with short scan times, the outstanding versatility of AiCE has many practical benefits

One of the main features of AiCE is its outstanding versatility as it can be used to examine a wide range of anatomical regions and supports many different scan sequences (Figure 1C).
In conventional systems, the quality of acquired MRI images always varies, even when the scan protocol has been optimized. This is because signal levels and details of the sequence vary depending on the patient's condition, the scan region, and the scan technique. Post-processing with AiCE, on the other hand, provides images in which the level of noise does not exceed a specified value, even if the original images are of poor quality. This makes it possible to ensure a certain level of image quality in almost all examinations, regardless of the expertise of the person who performs the scan. Additionally, AiCE minimizes the need to perform repeat scanning and thus helps to maximize examination efficiency (Figure 2A). Furthermore, AiCE supports non-contrast MRA, whole-body MRI, and other examinations which require longer scan times. As such, examinations requested by various clinical departments can be performed without placing an unreasonable workload on our staff or extending our operating hours. This has allowed us to expand the range of MRI examinations we are able to perform (Figures 1C and 2A).
The high-quality images and shorter scan times made possible by the installation of the Vantage Orian have increased our flexibility in handling urgent cases, and the greater versatility has led to a substantial increase in examination requests from various clinical departments. As a result, the number of MRI examinations performed in our department in July 2020 reached a record high of 111%, as compared to the monthly average for the previous year, despite the effects of the COVID-19 pandemic (Figures 2A, 2B). We are very proud to have achieved such a substantial increase in productivity during a difficult time in which many hospitals throughout the country were facing operational challenges.

Aiming for ideal medical care with kindness for every patient

We are committed to the idea that all patients should have equal access to required medical care. The staff in the Department of Radiology strive to ensure a comfortable examination environment for every patient.
In the past, patients needed to remain still throughout a long scan in a restricted space when undergoing an MRI examination. Therefore, MRI could not be performed for a significant number of patients who were unable to remain still or who were uncomfortable in confined spaces. Shorter scan times made possible by Vantage Orian combined with AiCE help to minimize motion artifacts (Figure 2A), and the

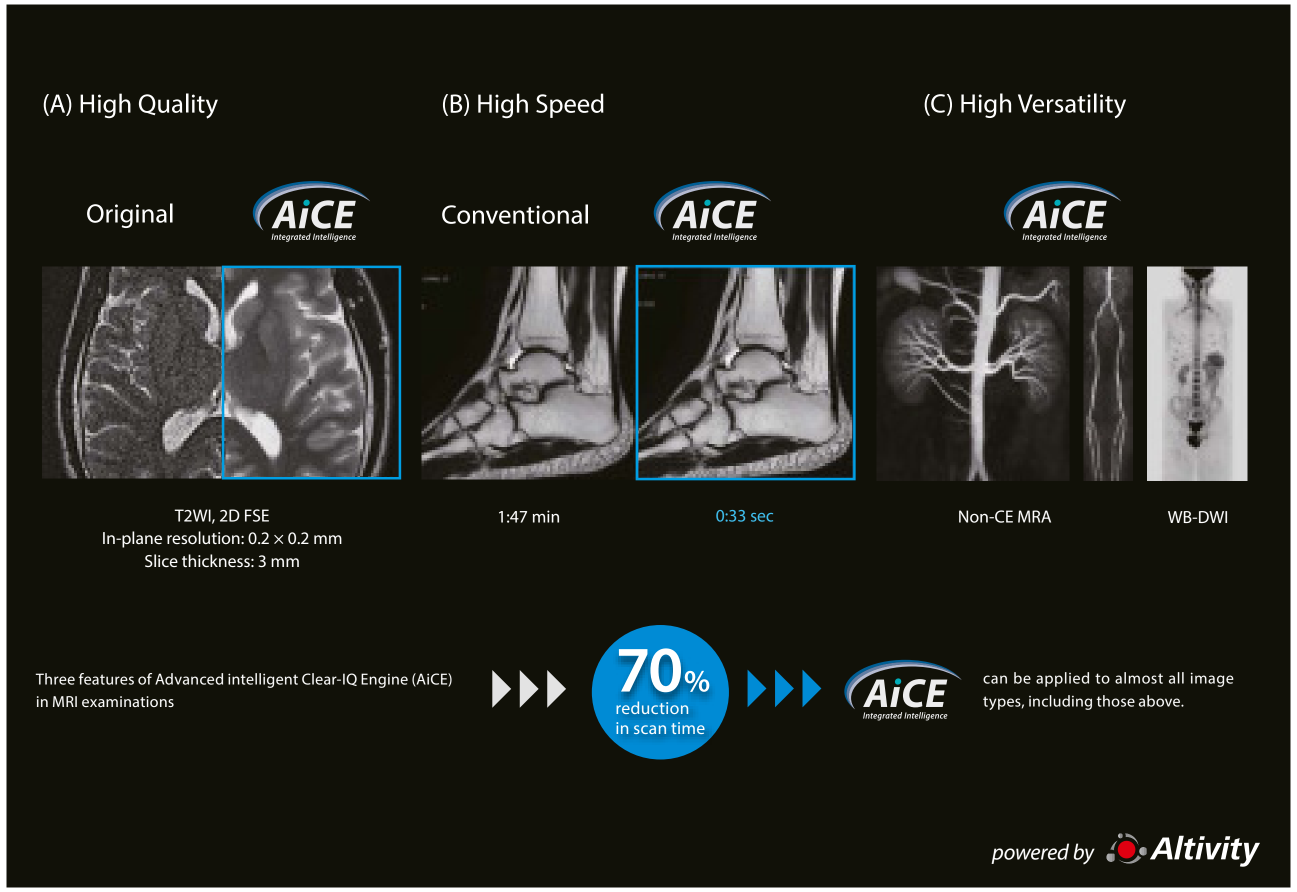


Figure 1: (A) High-quality images can be obtained by postprocessing without extending the scan time.
(B) Scan times can be reduced while maintaining excellent image quality.
(C) Examinations can be performed for many different anatomical regions using a wide variety of scan sequences.

feeling of spaciousness provided by the 71-cm large bore and MR Theater (Figure 3) help to reduce patient discomfort and stress (Figure 3). Non-contrast MRA (Figure 1C), which is a strong point of Canon MRI systems, is particularly valuable at our hospital, because we receive many examination requests for dialysis patients or elderly patients for whom contrast examinations are contraindicated. We believe that expanding the number of patients who are able to undergo MRI examinations will help us achieve our goal of equal care for every patient. //

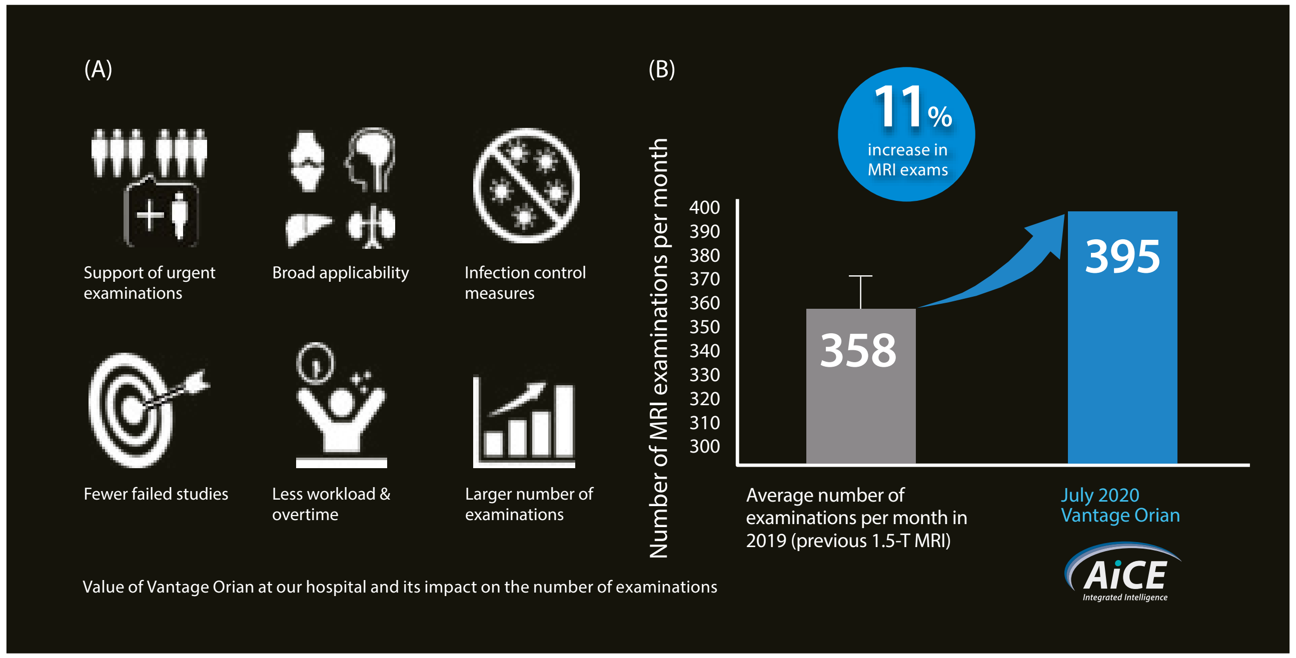


Figure 2: (A) Six advantages provided by Advanced intelligent Clear-IQ Engine (AiCE)
(B) Change in the number of MRI examinations per month before and after installation of Vantage Orian: Comparison of average number of examinations per month from January to December 2019 (previous 1.5-T MRI: gray) and number of examinations in July 2020 (Vantage Orian: blue)

Figure 3: MR Theater

Altivity Altivity is Canon Medical's new approach to AI innovation. It is a multimodality, overarching brand, which pulls together all the AI technology that Canon Medical provides under one name.

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