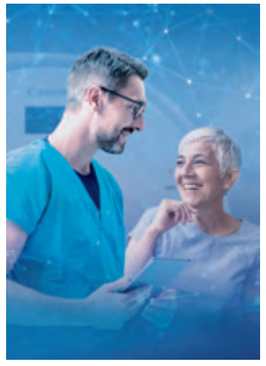
SPECIAL

visions

MAGAZINE FOR HEALTH PROFESSIONALS
Global Edition // MRI Special // No 02 // May 2022

The future of Intelligent MRI

Canon



Cover Image:
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// EDITORIAL

Let's Move!
Moving Beyond the Global Pandemic to Outcomes Driven Innovation

First of all, I would like to express my deep gratitude to all those involved in the healthcare industry who continue to work on the front lines, as the signs of recovery from the COVID-19 pandemic are only slowly and gradually improving. Under these difficult circumstances, Canon MR launched new solutions at RSNA 2021 that focus on efficient workflows to contribute to advanced medical imaging. We believe that Canon MR's new workflow solutions provide peace of mind for patients and simplified workflow for hospital staff.

At Canon we are convinced that AI-driven solutions, particularly these new solutions developed and incorporated on Canon medical equipment, will support hospital staff and administrators, enabling them to respond to the significant changes that have occurred in the healthcare environment. With this in mind, have recently launched Altivity, our bold new approach to AI innovation that uses smart technologies to make a whole new level of quality, insight and value across the entire care pathway possible. Moving forward when we talk about AI, it will be in terms of Altivity, which is Canon Medical Systems' vision of AI.

Within the ongoing challenging environment, at Canon MR, we are focusing on what we call the "3C's". "Confidence"; Image quality that allows you to make a diagnosis confident in the clinical results produced by Canon MR. "Comfort"; the comfort that patients need to experience when being examined with Canon MRI equipment, and "Cost-effectiveness"; The economic value that our MRI equipment delivers to healthcare facilities bottom-line from installation, through to ongoing operation, to transitioning to the next generation of medical equipment.

Focusing on these "3C's" and proposing even better solutions is our mantra for contributing to an ever changing healthcare environment.

MRI plays a critical role in diagnostic decision-making; yet is still unavailable in many parts of the world due to budget and space limitations, along with the clinical and technical expertise required to operate and maintain an MRI machine. We also know that the capability to image effectively across a broad range of diseases without radiation is vital to both patients and radiologists, and we have a burning passion to expand MRI to support advanced medical diagnosis.

In this edition of MR VISIONS Magazine, we are very proud to introduce many exciting developments that we have been working on, and welcome you to take a deeper look at Canon MRI. We hope you will be intrigued and educated by what you learn, and appreciate the value that Canon MRI can offer your facility. At our heart, we are, and must continue to be, collaborators with more and more global partners, and we are motivated to be on this journey with you. As we deepen our footprint and commitment in this important imaging modality, in 2022 we want to demonstrate our commitment to 'Outcomes Driven Innovation', which as always is underpinned by our 'Made for Life' philosophy.

Masato Uchikoshi
Senior Manager / Director,
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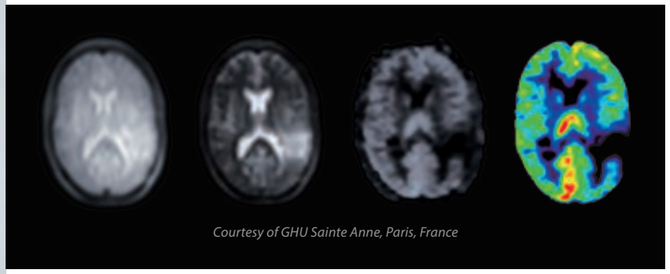

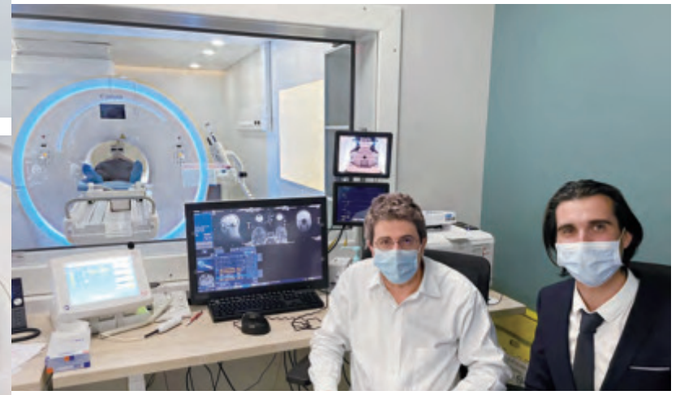

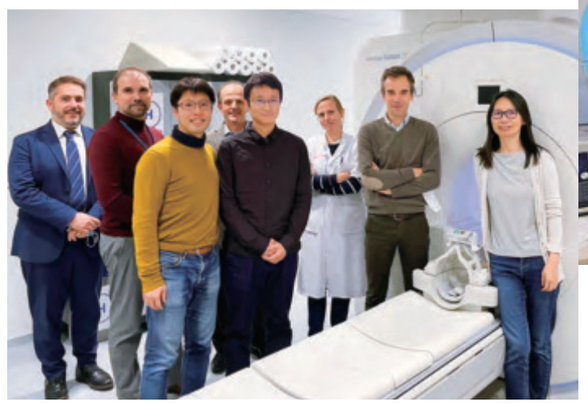

Introducing Altivity – Redefining the Role of AI in Healthcare

"One of the greatest things about the healthcare industry is the sheer speed at which it seems to evolve. I'm constantly amazed by the passion, dedication, and expertise demonstrated by our leading healthcare innovators, particularly in the area of AI." Toshio Takiguchi, CEO, Canon Medical Systems.

Just recently, Canon Medical Systems (herein after Canon Medical) launched its bold new approach to AI innovation…Altivity. We are extremely proud of this development, as it consolidates our range of deep learning and machine learning technologies to help clinicians deliver better outcomes to their patients and their business. If nothing else, the last twelve months have shown to us how adaptable and ready for change we need to be. The strain placed on healthcare systems by COVID-19 has pushed clinicians to their limits. Incidences of cancer, heart disease, and stroke are rising. And the increasing complexity of patient data is creating new opportunities that could easily be missed without insights and guidance from the right technology.

For many, these issues represent overwhelming challenges that are too difficult to resolve or require too great an investment. For us, however, we see them as opportunities for growth. At a time when resources are limited, we are doing everything we can to help our customers deliver informed healthcare with efficient workflows, so their patients can access the tailored treatment they need. And we are doing it with the power of AI.

Canon Medical has been steadily redefining the role of AI in healthcare, starting with our Advanced intelligent Clear-IQ Engine. Initially developed for CT, Canon Medical quickly deployed this Deep Learning Reconstruction technology across MRI and PET-CT systems to help speed up scan times and improve image quality. Next, came the launch of Automation Platform and the Stroke CT Package, both of which were designed to enhance clinical confidence and streamline workflows with the power of deep learning technology.

More recently, Canon Medical has transformed the ultrasound space with AI innovations that revolutionize clinical workflows. Through leveraging the power of AI, Canon Medical has been able to automate standardized serial measurements to increase clinical productivity and reporting accuracy.

As ever, our vision is to build a future where every individual receives the diagnosis and treatment that they need to live their lives to the fullest. While this won't happen overnight, I know that it starts with systems and solutions that are "Made for Life".

Toshio Takiguchi
CEO
Canon Medical Systems Corporation

What is Altivity?

Altivity is a new AI innovation brand from Canon Medical that consolidates machine learning and deep learning technologies. It reflects our bold new approach to AI, using smart technologies to make a whole new level of quality, insight and value across the entire care pathway possible.

Informed healthcare
Altivity is here to help your clinical confidence with high-quality images and applications that help you make informed decisions in real-time, at the point of delivery.

Fast, tailored care
Altivity has been created with your patients in mind to deliver the fast and accurate results they need for a more personalized treatment approach.

Efficient workflows
Altivity helps create simple, streamlined AI-driven workflows that optimize resource deployment and ensure your teams have the insights they need to work smarter every day. //

Canon
CANON MEDICAL

Made For life

Let's move with intelligent solutions for the MRI suite.

Always be there for your patients while efficiently and quickly producing high quality MRI exams.

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

Let's Move with Intelligent Solutions for the MRI Suite.

Shinsuke Komaki, Takeshi Ishimoto, Mark W. Golden, Yutaka Hoshiyama

In March 2020, the World Health Organization declared the novel coronavirus outbreak to be a global pandemic. Many countries and regions are still suffering from the effects of this worldwide health crisis.

As physicians and other healthcare professionals come into close contact with patients, who are in highly-stressful situations on a daily basis, it is essential that they have sufficient knowledge and skills in infection control, that they institute and implement appropriate preventive measures, and that they ensure a safe environment to prevent themselves from becoming infected or serving as vehicles for the spread of infection[1]. Within the extraordinary circumstances that we face today, healthcare professionals must provide efficient and high-quality medical care to patients, while avoiding human error, despite challenges, such as shortages of trained staff.

Canon is committed to reducing the burden on patients who undergo MRI examinations, on healthcare professionals who are involved in performing examinations, and on physicians who interpret the acquired images. Our research and development teams have carefully evaluated not only the workflow during actual image acquisition, but also every step in the overall diagnostic pathway, and have developed a number of new workflow solutions, such as Tablet UX, Ceiling Camera, and Auto Scan Assist. These solutions are examples of Canon's commitment to promoting patient-centric healthcare, while minimizing the burden on all healthcare professionals.

New workflow solutions help save time and improve the experience for patients and staff.

Background

As a noninvasive imaging modality that does not require exposure to X-Ray, MRI has a wide range of clinical applications. MRI is the modality of choice for evaluation of emergency patients with strokes and other serious conditions. However, the time required for MRI examinations is relatively long, ranging from 15 to 60 minutes. As a result, MRI departments in all parts of the world tend to be extremely busy, with full examination schedules and waiting times of several weeks. Patients undergoing unscheduled examinations are often required to remain in the waiting area for quite a long time.

Due to recent advances in the operation technologies of MRI systems, high-speed scanning techniques have been introduced and acquisition times have been substantially reduced. However, in addition to the actual scanning time, MRI examinations require careful patient preparation, including the identification of ferromagnetic implants, measures to minimize discomfort in certain body positions during examination, avoid allergic reactions to contrast agents, and so on. The time and effort required for patient preparation have barely changed in the past two decades, since the early years of MRI.

Towards saving time and reducing the burden on patients, radiological technologists, other medical staff involved in examinations, and interpreting physicians, Canon carried out a detailed evaluation of the overall workflow of MRI examinations. As a first step, Canon has introduced Tablet UX and Ceiling Camera as innovative solutions for improving workflow, from initial patient preparation, to moving the patient into the examination room, setting the RF coil, and placing the patient in the MR gantry.

Help patients relax knowing you are always by their side with our Tablet UX

Before starting an MRI examination, it is essential to check the patient for the presence of ferromagnetic implants, take measures to minimize pain that may be experienced in certain body positions, and to avoid possible allergic reactions to contrast agents. According to the basic operating principles of MRI, scanning is performed while a specified range of the body is positioned within the magnetic field. The operator, therefore, needs to accurately determine the region of interest and acquire all the image data required for diagnosis. After receiving the patient information from the intrahospital electronic health information system (HIS), the operator confirms the information received by talking with the patient to ensure that the examination is performed correctly and safely. If any inconsistencies are found between the information in the health record and the information reported by the patient, the operator needs to return to the health information system and recheck the examination request submitted by the physician. There has previously been very little improvement in these time-consuming preparatory procedures.

Help patients relax with a more seamless process from waiting room to completed exam.

Canon's newly introduced Tablet UX stores the examination requests on a web server in the host PC of the MRI system, allowing examination requests to be viewed, edited, and added directly from the tablet. The list of examinations can also be displayed as a worklist. The specific page for the patient can be opened while standing at the patient's side, allowing the operator to confirm the patient's identity, the presence of ferromagnetic implants, and so on, together with the patient, while viewing the patient information displayed on the tablet. Any corrections required to the information can be entered directly from the tablet. Personal information provided by the patient can also be captured and saved using the camera built into the tablet. In addition, because the tablet is linked with the MRI system, the operator can select the scan region, the RF coil, and the scan protocol from the tablet to register a scanning plan to the MRI system console during patient preparation. Previously, the operator had to rush to confirm the examination request and set the scan protocol, however when the Tablet UX is used, the operator has ample time to select the RF coil and set the scan protocol before starting the examination. The time saved with Tablet UX reduces the time pressure on the operator, leading to greater peace of mind, fewer errors, and higher examination success rates. The operator can also spend more time talking with the patient, helping to relieve the patient's anxiety and enhance their sense of security. The reduced stress on both the patient and the operator can ultimately lead to improved image quality and more rapid decision-making when formulating treatment plans.

The portable Tablet UX makes confirming patient information simpler and quicker.

The Tablet UX enables the ability to remotely confirm the status of ongoing exams.

The new Ceiling Camera assists with accurate and efficient set-up.

Optimize efficiency and accurate set-up with our Ceiling Camera

Patients often feel most anxious when the examination is starting. The operator checks the target region on the examination information terminal, selects the RF coil to be used, and sets it on the patient. The selected coil may sometimes be unsuitable due to the patient's physical condition, such as discomfort or a limited range of joint motion, and the coil may need to be reset several times. The coil sensitivity may also be insufficient, and repeat scanning using a different coil may be necessary. In many cases, all these issues can be avoided if the operator simply spends more time talking with the patient before starting the examination. When Tablet UX is used, the operator can select the coil and scan protocols quickly and spend more time interacting directly with the patient before starting the examination. When preparing for scanning, with the patient lying on the patient table, the coil that has been selected using the tablet can be displayed on the intelligent monitor on the front of the system. This allows the operator to reconfirm that the most suitable coil has been selected and perform coil setting more efficiently. The additional time made available by the optimized patient preparation workflow helps to give the patient a greater sense of security. The displayed coil setting position (center position) as viewed from the Ceiling Camera based on the preregistered scan region is

The Ceiling Camera utilizes advanced Canon technology.

very helpful to the operator when preparing for the examination. After the coil specified on the intelligent monitor has been set, all the operator needs to do is to select [MOVE] on the intelligent monitor and send the patient into the gantry. The system automatically performs scan position setting inside the gantry. The manual scan position setting procedure in the previous workflow (i.e. projecting a red laser beam and finely adjusting the couch position to align the center of the coil with the center of the laser beam) is fully automated in the new workflow.

Improved workflow for the benefit of everyone

Time is one of our most precious commodities. This is equally true for patients. Improved workflow allows examinations to be performed more smoothly and in a shorter time. The time saved by optimizing overall examination workflow leads to greater peace of mind and helps to ensure a successful examination. Shortening the time required for MRI examinations allows patients to return to their loved ones more quickly.

The improvements in workflow described above are technological solutions that reflect a strong commitment to improving the total patient experience. Canon will continue to develop solutions that help save the valuable time of all patients and staff.

Utilizing AI to standardize and simplify MR Scan Planning with Auto Scan Assist

The next generation of Auto Scan Assist technologies further enhances workflow and ease-of-use for all levels of experience, even when performing complex examinations such as abdominal, prostate and whole spine MRI procedures.

The medical environment has changed dramatically due to the COVID-19 pandemic. With the pandemic still ongoing, its effects will continue well into the future. Globally, there is a shortage of trained medical personnel, including doctors and experienced MR technologists. Due to the high infection rate and mandatory medical leave, inexperienced MR technologists are often required to perform high level MR examinations without proper supervision and/or assistance from the more experienced MR technologists. Moreover, MR examinations are more complex than other modalities, and the users' level of experience is extremely important for maintaining image quality. When an inexperienced technologist is required to perform these complex examinations independently, image quality and correct anatomical positioning can cause difficulty in accurate diagnosis that ultimately demands a repeat scan and/or an increase in overall MR examination times. Canon's Artificial Intelligence Auto Scan Assist Automatic Technology allows MR Technologists with different levels of experience to perform complex MR Procedures easily, while enhancing workflow and reproducibility from patient to patient.

Canon first implemented Auto Scan Assist Technologies in 2014, with the introduction of CardioLine which was the first-generation of Auto Scan Assist. Following this, Auto Scan Assist technologies were expanded to enhance workflow and auto positioning for multiple MR examinations and body regions:

New workflow solutions for patients and staff.

- NeuroLine+
- SUREVOI Knee & KneeLine+
- SpineLine+
- SUREVOI Cardiac & CardioLine+

The newest generation Auto Scan Assist is now available, further complimenting Canon Medical Systems' Artificial Intelligence (Altivity) family of technologies focused on improving accuracy for MR procedures such as Liver, Prostate and Whole Spine Imaging.

- **SUREVOI Liver & LiverLine+**

Automatic slice orientation and positioning for 2D RMC Probe, Visual Prep, MRCP and Liver examinations (Figures 1, 2, and 3).

- **W-SpineLine+**

Automatic slice orientation and positioning for Sagittal, Coronal, and Axial planes in the cervical, thoracic, and lumbar regions for whole spine examinations (Figures 4, 5, and 6).

- **ProstateLine+**

Automatic slice orientation and positioning for Axial, Sagittal and Coronal planes based upon Pi-Rad Standards. Furthermore, the users can select a more detailed and exact slice orientation and positioning parallel and/or perpendicular to urethra for prostate examinations (Figures 7 and 8).

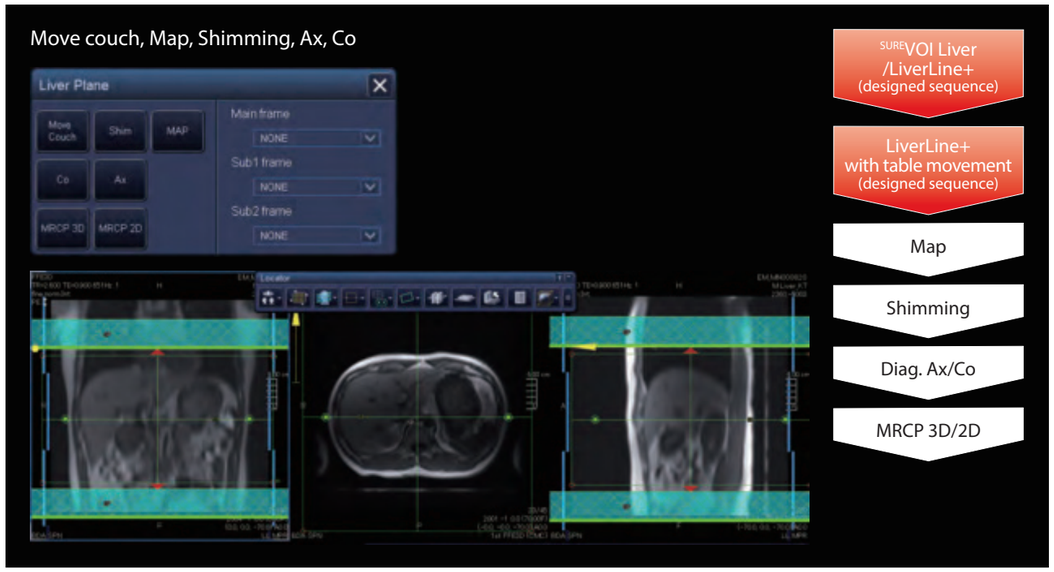

Figure 1: Target planes (7 types in total): from FFE3D

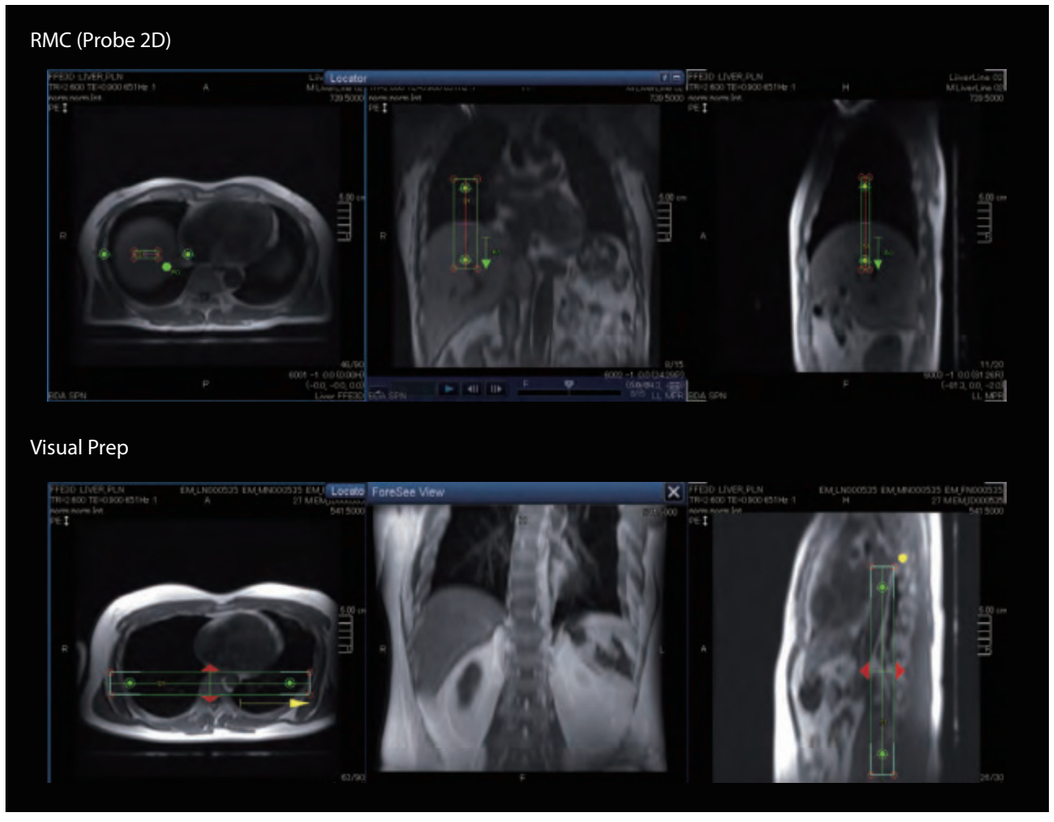

Figure 2: Target planes (7 types in total): from FFE3D

Verification study

A verification study was performed to determine and evaluate the clinical usefulness of Auto Scan Assist. In this study, three operators were measured and compared for the operational steps and slice orientation/positioning time, with and without Auto Scan Assist, while performing liver/MRCP, whole spine and prostate examinations on a volunteer (Tables 1 and 2).

- Liver & MRCP: 8 sequences
- Whole Spine (cervical spine, thoracic spine, lumbar spine: 13 sequences
- Prostate: 5 sequences

Results from this verification study using the Welch Test for statistical analysis determined a reduction for both operational steps and slice orientation/positioning time reduction for both liver/MRCP (42% operational steps and 34% slice orientation/positioning time reduction) and prostate (56% operational steps and 40% slice orientation/positioning time reduction), with a significant reduction for whole spine examinations (80% operational steps and 75% slice orientation/positioning time reduction) (Figure 9).

In conclusion, the evaluation by introducing Auto Scan Assist, demonstrated the possibility to reduce the number of operational steps and overall examination times, while reducing the burden on the operator. W-SpineLine+ demonstrated a significant overall reduction in operational step and scan time reduction.

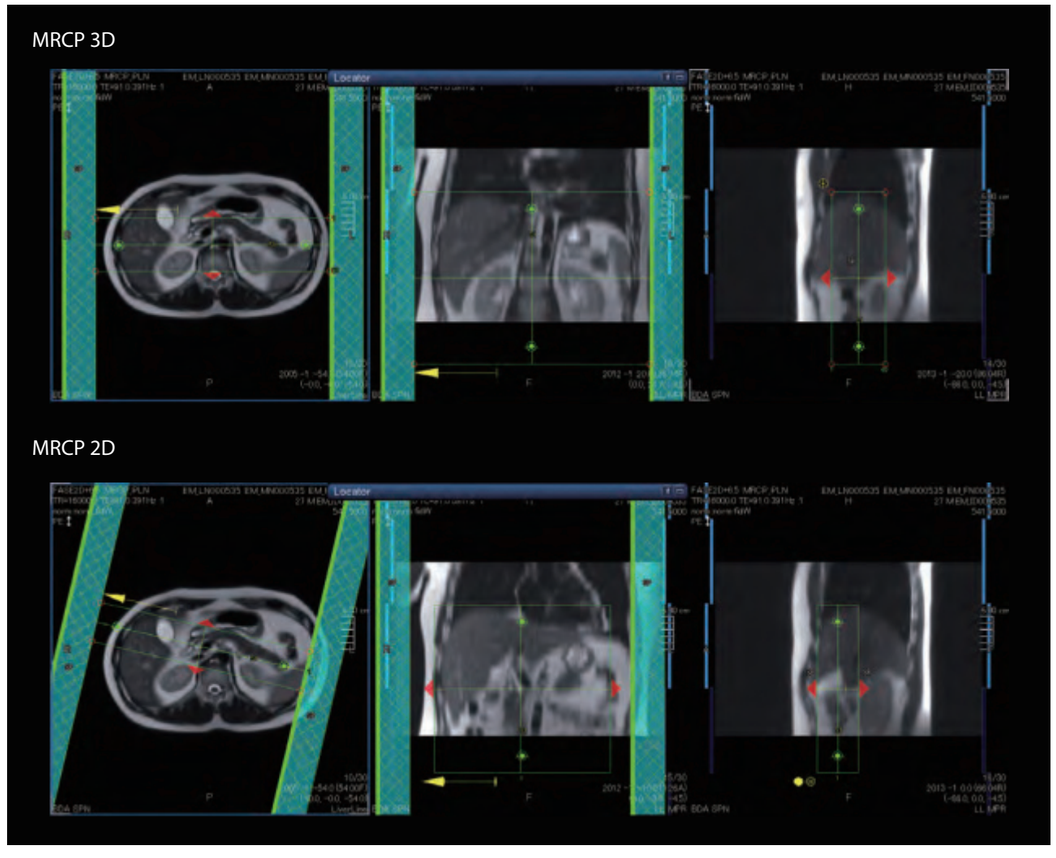

Figure 3: Target planes (9 types in total): MRCP

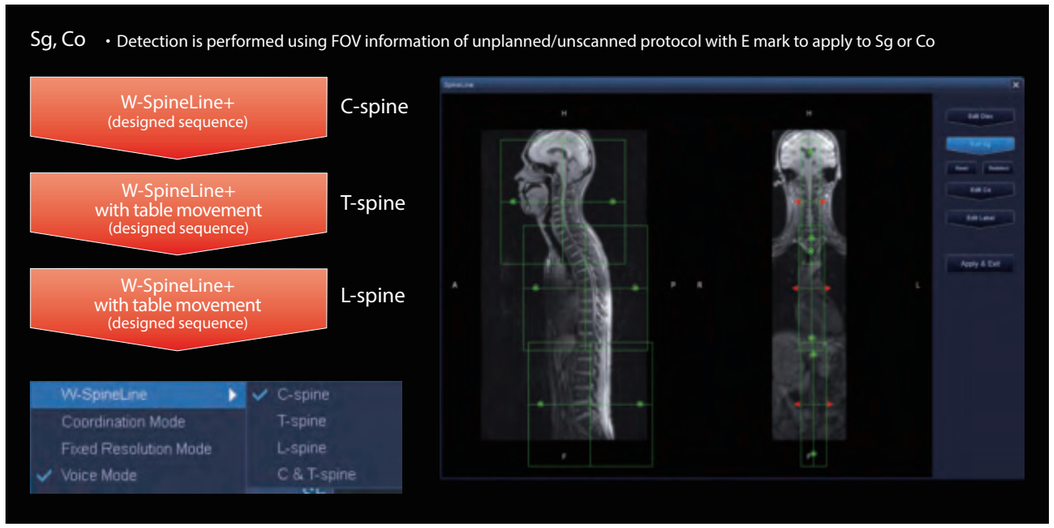

Figure 4: Detection of slice position

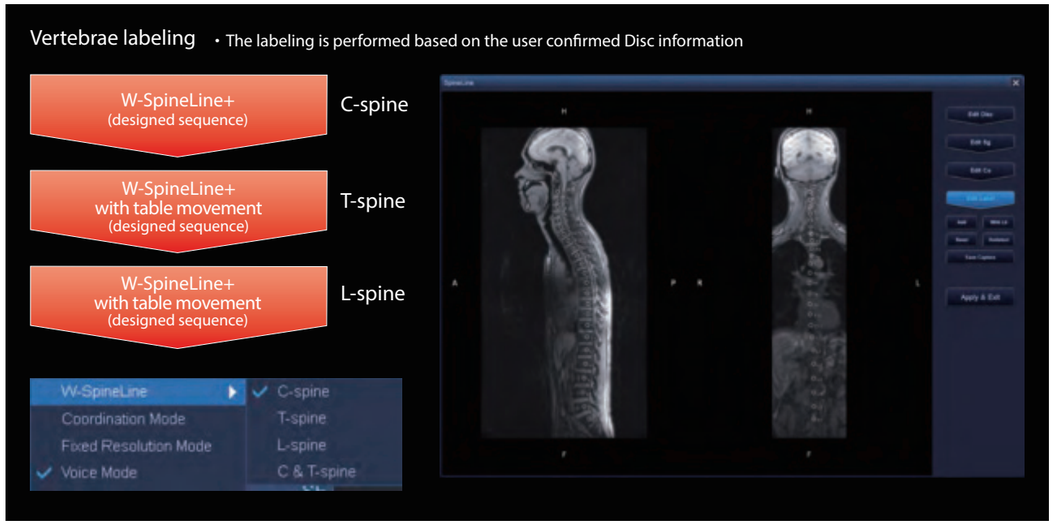

Figure 5: Automatic Labeling

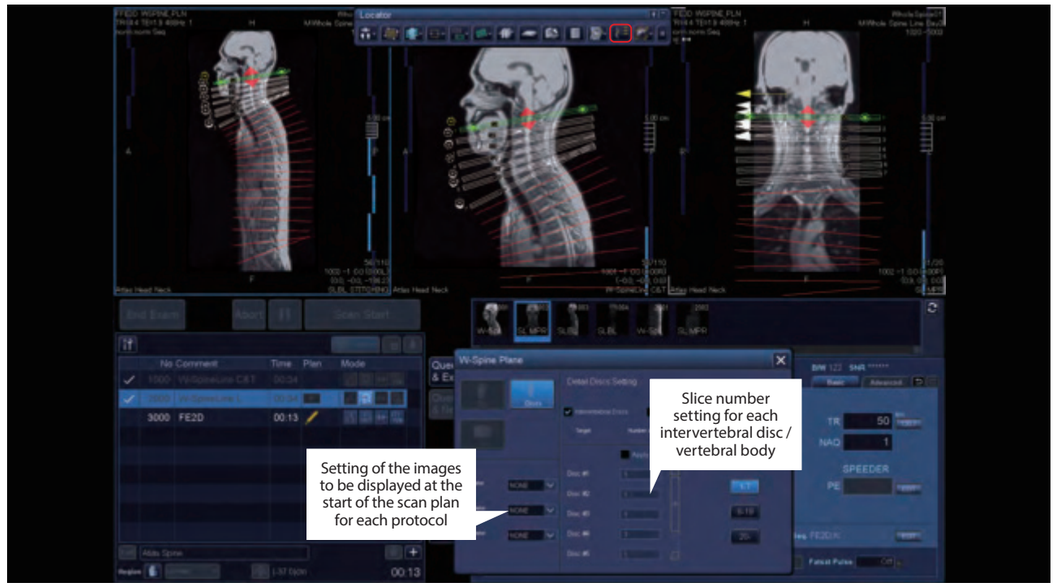

Figure 6: W-Spine Auto-Plane Positioning

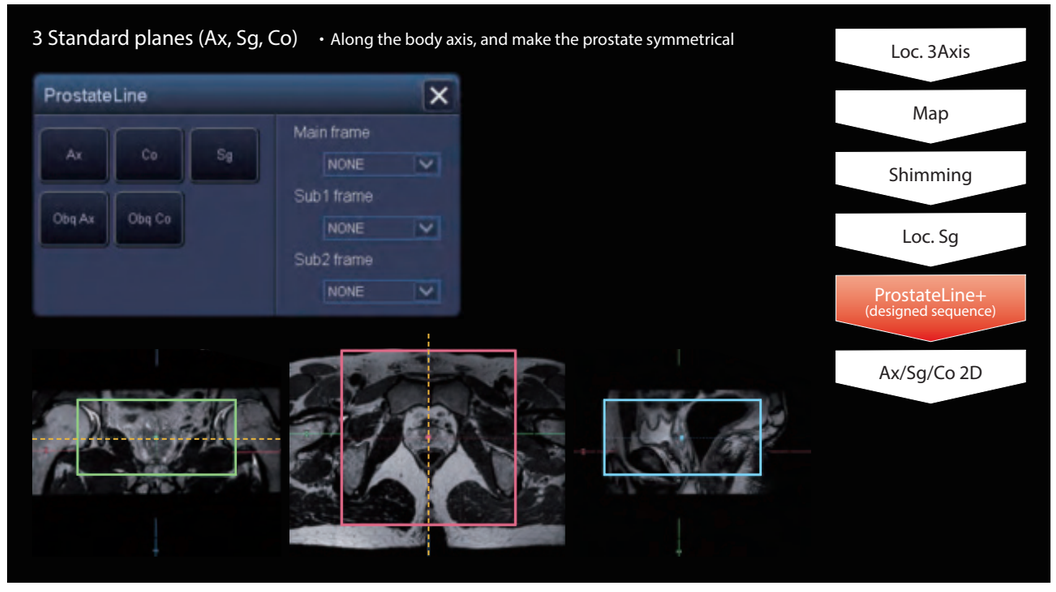

Figure 7: Target planes (5 types in total)

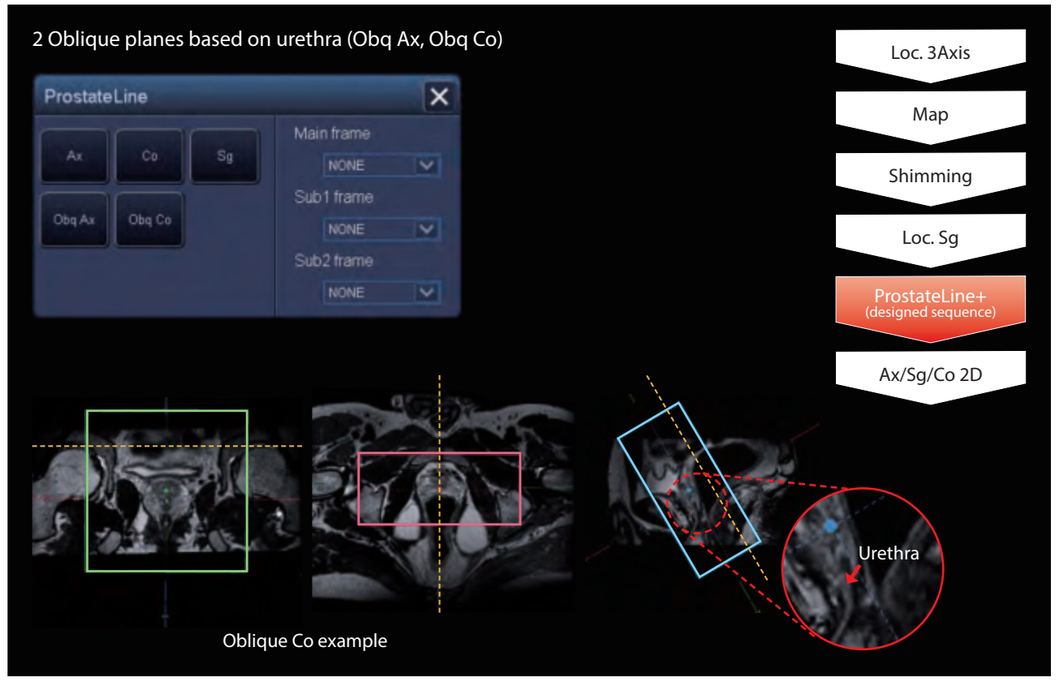

Figure 8: Target planes (5 types in total)

Table 1: Operational Steps

Examination	Without Auto Scan Assist	With Auto Scan Assist	Reduction %	P-Value
Liver/MRCP	54	31	42%	N/A
Prostate	39	17	56%	N/A
Whole Spine	176	35	80%	P<0.05

Table 2: Slice Orientation / Positioning Time (seconds)

Examination	Without Auto Scan Assist	With Auto Scan Assist	Reduction %	P-Value
Liver/MRCP	206 sec.	135 sec.	34%	N/A
Prostate	128 sec.	76 sec.	40%	N/A
Whole Spine	667 sec.	162 sec.	75%	P<0.05

Whole spine examinations may require additional time and effort to set up and acquire images, especially for a less experienced operator. However, by introducing Auto San Assist, errors can be reduced, and time saved by reducing variability between operators allowing for safe implementation of MR examinations while being able to prepare for upcoming scheduled procedures. Auto Scan Assist not only reduces the burden on the operator, but further improves overall workflow and the potential for the number of MR examinations and procedures carried out throughout the day. The workflow enhancement ultimately leads to the patient's comfort by reducing overall examination times.
Since time is precious, our mission is continual workflow improvement to improve the users' experience, while further reducing MR examination times. //

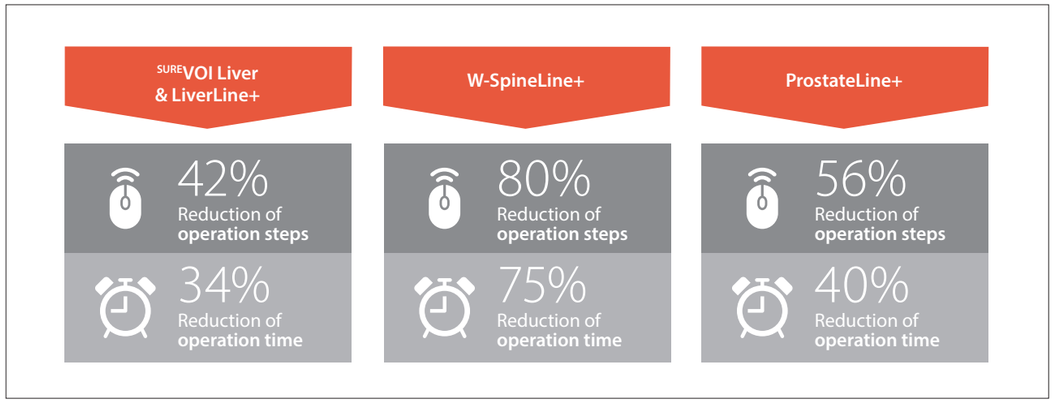

Figure 9: Improvement of workflow
Reduction of operation steps and operation time by introducing Auto Scan Assist*

** Image selection, plan setting, saving are included as the results of internal investigation*

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References
[1] *https://www.cdc.gov/coronavirus/2019-nCoV/hcp/infection-control.html*
Excerpt from the "COVID-19 Infection Control Guidelines" issued by the US CDC.

VISIONS spoke with Dr. Hikaru Fukutomi, on his secondment and research collaboration with the IBIO, Bordeaux University, France.

Cutting Edge Collaboration in MRI

For almost a decade, the University of Bordeaux, in France, and the University of Kyoto, in Japan, have collaborated on research in many areas, including magnetic resonance imaging. The collaboration between the two world class institutions have led to many advances in healthcare. Dr. Hikaru Fukutomi is a Neuroradiologist from Kyoto University, who is completing a three-year research secondment at the Bio Imaging Institute (French: IBIO) at the University of Bordeaux as part of this collaboration. He explained how the Canon Vantage Galan 3T / ZGO* system at Bordeaux University has enabled him to explore new research techniques.

Bordeaux and Kyoto Universities have run an exchange for medical students since 2007, but the collaboration between the two institutes deepened in 2014 through development of the Bordeaux Initiative of Excellence[1] and the Kyoto SPIRITS[2] program. The partnership has contributed over the years to expanding global knowledge in healthcare, chemistry and computer science.

Before starting his secondment at Bordeaux University, Dr. Fukutomi was a Radiologist with radiology pioneer, Professor Kaori Togashi at Kyoto University.

"My work in Kyoto included clinical practice and some research," he said. "At Bordeaux, I have focused on research only with a clinical link to Kyoto. For this, I work with the Canon Vantage Galan 3T / ZGO MRI system."

Dr. Fukutomi's research has started exploration of the potential of a non-contrast injected imaging technique. The new technique might provide a way of imaging in a simpler

From left to right: Bruno Triaire (Canon Medical Systems Corporation), Mr. Laurent Denat (IBIO), Dr. Taka Yamamoto (IBIO), Prof. Vincent Dousset (IBIO), Dr. Hikaru Fukutomi (IBIO), Dr. Amandine Crombe (IBIO), Prof. Thomas Tourdias (IBIO), Bei Zhang (Canon Medical Systems Europe)

** Vantage Galan 3T / ZGO is a limited pre-market research system. Vantage Centurian, the commercial version of Vantage Galan 3T / ZGO, is now available in certain regions.*

Bio Imaging Institute (front) and University Hospital of Bordeaux.

and safer way. His initial work was recently awarded by the ISMRM – International Society for Magnetic Resonance in Medicine.

"The Vantage Galan 3T / ZGO has enabled us to make very high-resolution images, so that we can achieve visualization of the small structures involved in my research," he added.

"After I had used AiCE, I realized that it's very good technology for research and clinical work."

Dr. Hikaru Fukutomi, University of Bordeaux, Bio Imaging Institute (French: IBIO)

Canon's Vantage Galan 3T / ZGO, at the Bio Imaging Institute, University of Bordeaux.

Advanced technology

The Vantage Galan 3T / ZGO with powerful gradients and high-end RF coils technology, is an ideal device to support this kind of research. The wide range of advanced pulse sequences, including the latest innovation, such as Advanced intelligent ClearIQ Engine (AiCE) and Compressed SPEEDER, provide efficient solutions to the researchers, while bringing outstanding image quality and resolution.

"AiCE is a very great technology," said Dr. Fukutomi. "It increases SNR - Signal to Noise Ratio, so that we can shorten the image scanning time, and get higher resolution, clinically beautiful images."

"When I first came across this technology, I didn't know anything about it much and wondered if the process of removing noise would make it difficult to see change in the region being imaged," he continued. "However, I have never seen this occur. After I had used AiCE, I realized that it's very good technology for research and clinical work."

Dr. Fukutomi thinks that the further development of AI (Canon Medical Systems' AI technology is known as Altivity), will bring many benefits to research and clinical imaging.

"Before I started with my research as a Radiologist, AI had only just started to attract attention for use in clinical practice, I was concerned about a few things, but I changed my opinion about it," he remarked. "I began using AiCE at Bordeaux University and have found it very helpful. In fact, I cannot easily realize my study project without it."

"As far as my research field is concerned, AI helps us to for example, identify and recommend standard procedures," he continued. "For clinical work, AI can help us to reduce human errors and to reduce work time. While AI holds much promise, we humans still need to check the results, as with all developing technology. So, I think it will not replace human work in the clinical field completely. Speaking as a researcher though, it's a good topic, and I want to continue to use AI techniques."

Advancing knowledge

Dr. Fukutomi's study will develop in a next phase using clinical patient scans and beyond this into a clinical patient study.

"We are working towards an end-goal of non-contrast imaging through meeting the technical challenges involved in achieving that," he said.

"Canon's clinical scientists are very cooperative," he said. "If I have any clinical questions or requests for support, they will respond immediately. They help me on technical points, and we hold regular meetings. A wider team will come to Bordeaux when I can ask them some additional questions."

Dr. Fukutomi reaches the end of his three-year research secondment in 2022 and will return to Kyoto University in Japan, in September, this year. The University has also installed a Vantage Galan 3T MRI system with AiCE since he has been working in France, so he will be able to continue to use this system when he resumes work in Kyoto.

Working environment and Vantage Galan 3T / ZGO, at Bio Imaging Institute, University of Bordeaux.

Dr. Hikaru Fukutomi

Dr. Hikaru Fukutomi studied Medicine at Kyoto University in Japan and graduated in 2008. Between 2008 and 2010, he studied as a Junior Resident and following this, as a Radiologist until 2015. He then studied for a PhD, also at Kyoto University, which he obtained in 2019. He has published seven scientific papers and is a member of International Society of Magnetic Resonance in Medicine (ISMRM), the Japanese Society of Magnetic Resonance in Medicine (JSMRM), and Japan Radiological Society (JRS). In 2019, he started a three-year research secondment at Bordeaux University in France.

Dr. Fukutomi is married with two young daughters. His family has travelled with him to join him in France for the research, and they have greatly enjoyed their time experiencing life in a foreign country. //

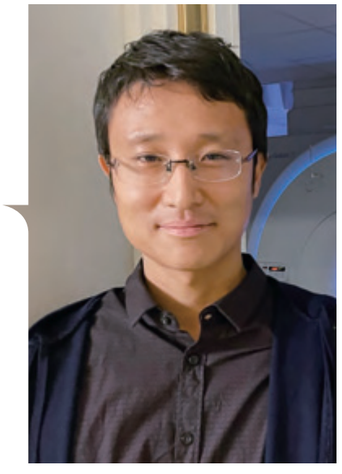
References

1 *Bordeaux Initiative of Excellence - the Bordeaux International Support – BIS program.*

2 *Kyoto SPIRITS program – Supporting Program for Interactive-Based Initiative Team Studies.*

"The Vantage Galan 3T has enabled us to make very high-resolution images, so that we can achieve visualization of the small structures involved in my research."

Dr. Hikaru Fukutomi, University of Bordeaux, Bio Imaging Institute (French: IBIO)



A New Approach to Stable MRI Exams

Shigeru Kiryu, M.D., Ph.D.

Changing Requirements of MRI Exams

The global COVID-19 pandemic has greatly changed the environment surrounding Radiology. In last year's RSNA2021, the theme of "Redefining Radiology" represented a defining frame for when we move past the pandemic. RSNA2021 highlighted workflow efficiency and patient-centeredness, while considering how to simultaneously maintain high-value imaging.

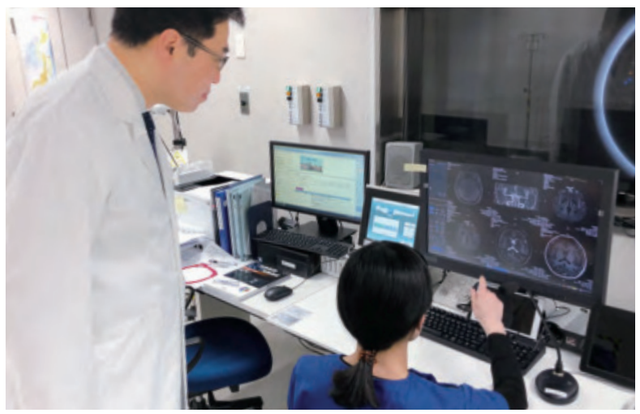
In order to provide high-value images, the key is how to avoid producing images with low diagnostic value. A typical example of a low diagnostic value image is an image with severe artifacts. In particular, when the artifacts cause difficulty in diagnosis, re-scanning may be required, impacting the overall efficiency of workflow. Certain MRI artifacts can be avoided by imaging conditions, and others are specific to patients due to motion. Even when simply referring to "motion", there are various types of motion, such as breathing, heartbeat, blood flow, and accidental movements, including swallowing or coughing during the examination. In addition, the pattern of the artifacts varies depending on the characteristics of the motion. It is not easy to control the patient's own motion, and it is possible to experience artifacts by accidental movement if the scan time becomes lengthened. Canon Medical Systems has commercialized new technology that suppresses these motion induced artifacts in order to improve workflow efficiency and provide stable exams, which I would like to introduce in the following paragraphs.

Prof. Kiryu (far right), with Department of Radiology staff from International University of Health and Welfare Narita Hospital, and Canon Medical representatives (suited in middle).

Counteracting Motion Artifacts

In principle, there are prospective and retrospective methods to suppress motion artifacts. The prospective method utilizes physical sensors (including camera observation in recent years), a specific sequence called 'navigator echoes', or a part of the collected data to observe body movements, then the effects of movement will be eliminated or corrected by the observation. Respiratory and ECG synchronization, Realtime Motion Correction (RMC) corresponds to this. This method can be used in combination with various sequences, and stable image quality can be obtained, but the scan time is often extended. Especially if the patient's breathing and heartbeat are not stable, the scan time may be nearly twice as long as expected, or data collection may not proceed, and the examination may be interrupted. Alternatively, one of the well-known retrospective methods is to collect data radially in the k-space and correct this data during reconstruction. Canon Medical Systems provides this type of application known as JET. JET is used in combination with FSE2D (Fast Spin Echo 2D) sequence and is a very effective body motion correction technique. However, since the k-space sampling pattern is different from Cartesian sampling, which is often used in clinical practice, the contrast of images is likely to appear slightly different from that of general images and a specific streak artifact can occur.

Iterative Motion Correction (IMC) application, a body motion correction technology which has recently been released by Canon Medical Systems, is equivalent to a retrospective method, but unlike JET, the data sampling pattern in the k-space is Cartesian. Therefore, this method addresses certain issues experienced with JET.



Prof. Kiryu reviewing images with a colleague.

Prof. Kiryu with Canon's research level system, Vantage Centurian.

Iterative Motion Correction (IMC) – an Alternative Solution

IMC is also used in combination with FSE2D sequences. In Canon's latest software release (V8.0), the main target is Brain FLAIR (fluid-attenuated inversion recovery) and C-spine T2WI.

IMC correction can be applied to the motion of a rigid body, such as the head. The motion of the rigid body is simplified to estimate and correct the amount of translation and rotation. The process is shown in Figure 1. In general, FSE acquires data for image creation in each shot (Echo Train). In the case of IMC, however, the additional data for motion detection is collected in the same shot. IMC always uses a kind of parallel imaging reconstruction so that FSE data acquisition is under-sampled, and it contributes to scan time as short as that for a routine clinical scan. As shown in Figure 1, there are two processes for rigid body correction. Initially, shot rejection process uses motion detection data to eliminate large motion data. After that, rigid motion correction process uses the remaining data and performs to estimate both the amount of motion (motion estimation) and the images without motion (image estimation) by solving the unknown parameters.

Image estimation process uses the Conjugate Gradient SENSE (SENSitivity Encoding) method to estimate the expected final reconstructed image from under-sampling collected

data[1]. Then, motion estimation process simulates k-space data with a certain amount of body motion by adding the motion parameters (translational and rotational movement amounts). The simulated data and the actual collected data are compared on an image domain to find the answer for the unknown parameters with minimum error. As the error cannot be minimized by this processing only once, both image estimation and motion estimation are repeated alternatively and iteratively. Finally, it is possible to obtain a reconstructed image that suppresses the influence of movement.

IMC corrects not only rigid motion, but also non-rigid motion. This correction process is shown in Figure 2.

As shown in the figure, rigid body motion correction is first performed using a 2D navigator echo. This is different from the previously explained method that executes rigid body correction and parallel imaging reconstruction alternatively, however, the target for motion to be corrected is the same translation and rotational movement. Shot rejection is then performed to maintain the correction accuracy by excluding the data with large changes. Then, non-rigid body correction process is executed. The non-rigid body correction utilizes the process of creating synthetic data from under-sampling data in the k-space domain[2]. One line in the Read-Out (RO) direction is considered in the k-space of the acquired data after rigid body correction. The acquired data are compared with the synthetic data created by estimating from the surrounding data. If the consistency is poor, the acquired data is likely to be affected by the patient's motion, and it is replaced with the synthetic data. Thus, it is possible to prepare k-space data that suppresses the influence of motion as a whole, and finally, a reconstructed image in which the motion is suppressed can be obtained.

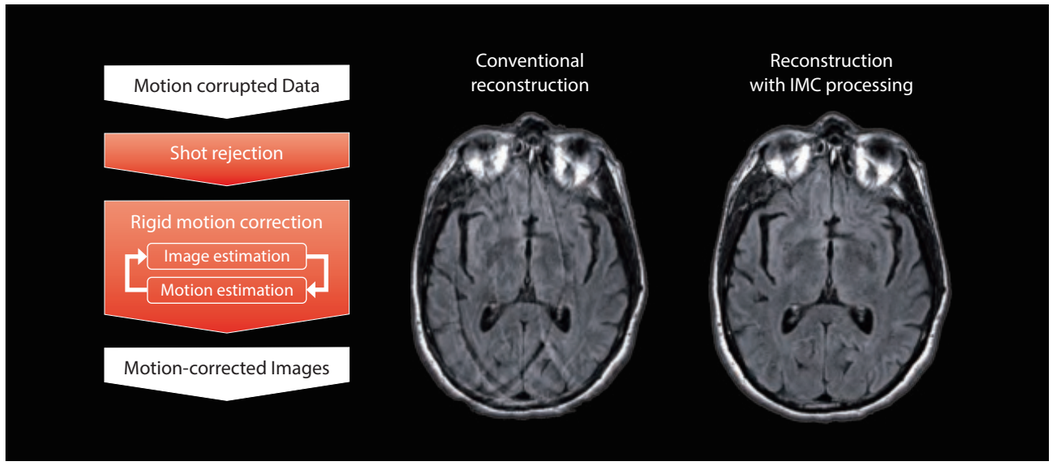


Figure 1: Flowchart of Iterative Motion Correction reconstruction processing for rigid motion (left) and the comparison of the images with / without IMC (right)

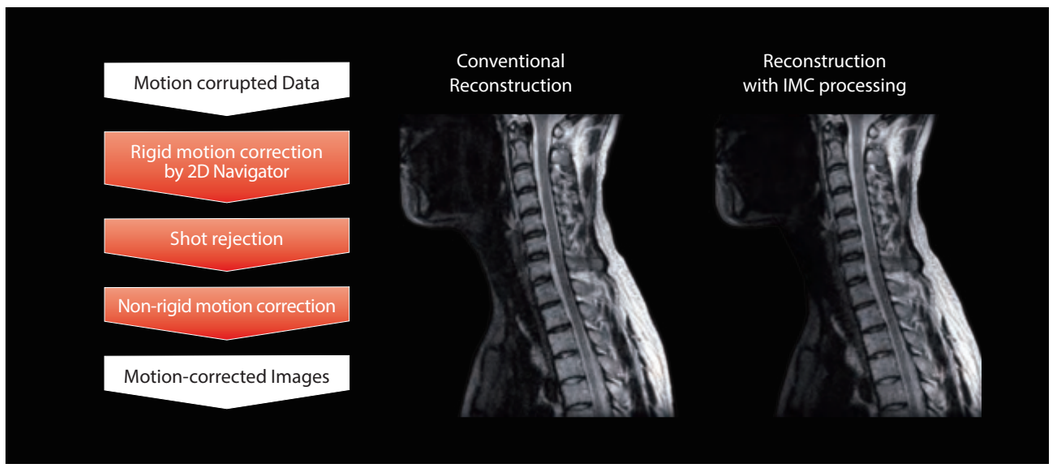


Figure 2: Flowchart of Iterative Motion Correction reconstruction processing for non-rigid motion (left) and the comparison of the images with / without IMC (right).

Example cases of Iterative Motion Correction

The effectiveness of IMC is shown in Figure 3. In this example, the volunteer intentionally moved during the scan. It is clear that the artifact of the motion is well suppressed by applying IMC.

As mentioned earlier, the advantage of this IMC method is Cartesian collection, in which sampling patterns in k-space are conventionally used. As a result, it is possible to replace routine examinations without additional consideration.

The IMC can also be used in conjunction with Deep Learning Reconstruction, Advanced intelligent Clear-IQ Engine (AiCE). As shown in Figure 4, by using IMC in combination with AiCE, the stability improvement by SNR and motion suppression makes it possible to provide more valuable images, and it is highly anticipated that such new technologies improve the examination quality and future diagnosis in the post-COVID-19 Radiology world. //

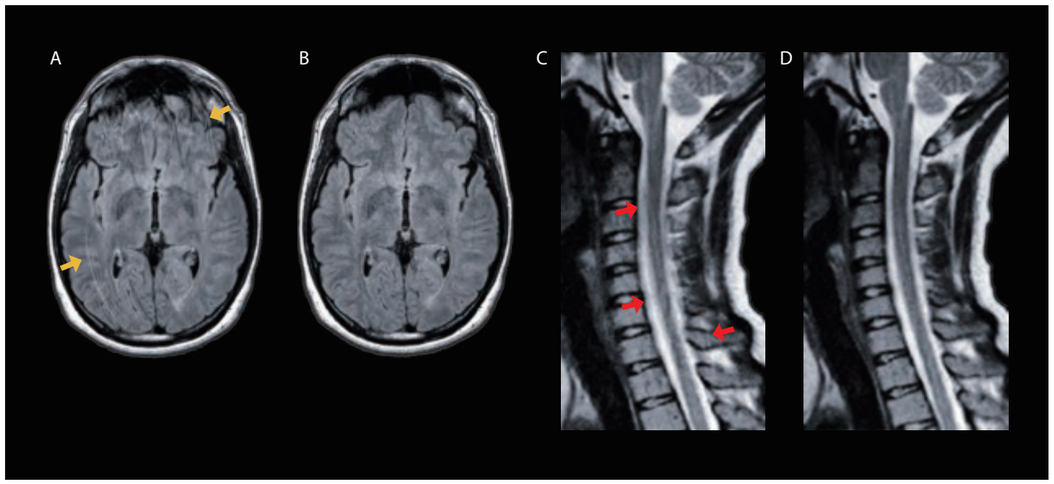


Figure 3: Example of the images with / without Iterative Motion Correction reconstruction processing. A and C show the original images which have artifact induced by motion during the scan (yellow and red arrows). B shows the reconstructed image with IMC processing (only rigid motion correction) and D shows the non-rigid motion correction processed image. IMC effectively demonstrates reduced motion artifacts.

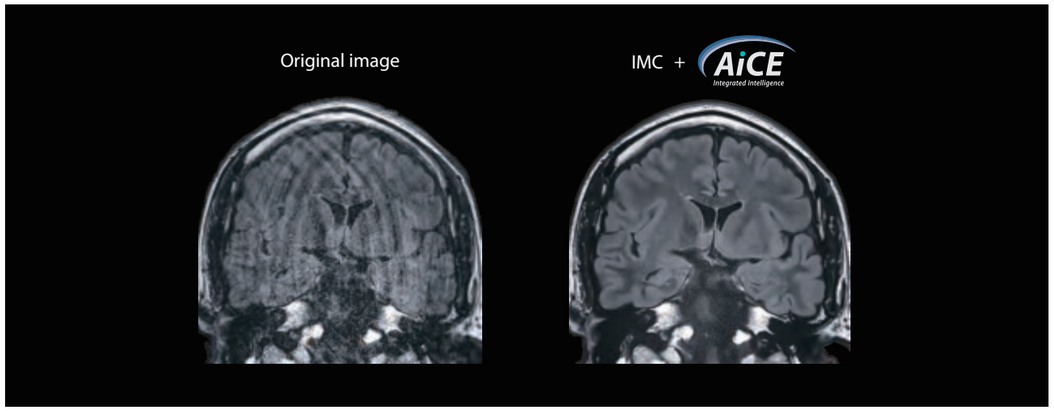


Figure 4: Example of both IMC and AiCE applied image. As compared with the original image, the processed image (IMC with AiCE) has better image quality in terms of SNR and motion artifact suppression.

Four Canon MRI systems are in operation at the International University of Health and Welfare Narita Hospital. 2 × 1.5T, 1 × clinical 3T and 1 × research grade 3T systems are in operation, contributing to daily medical care.

Premium 1.5T MRI, Vantage Orian / XGO.

Research grade 3T MRI, Vantage Centurian.

Routine 1.5T MRI, Vantage Orian.

Premium 3T MRI, Vantage Galan 3T.

International University of Health and Welfare Narita Hospital.

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and Welfare Narita Hospital, Japan.

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[1] *Pruessmann KP, et al., Magn Reson Med., 46:638-651, 2001*
[2] *Huang Feng, et al., Magn Reson Med., 64(1):157-166, 2010*

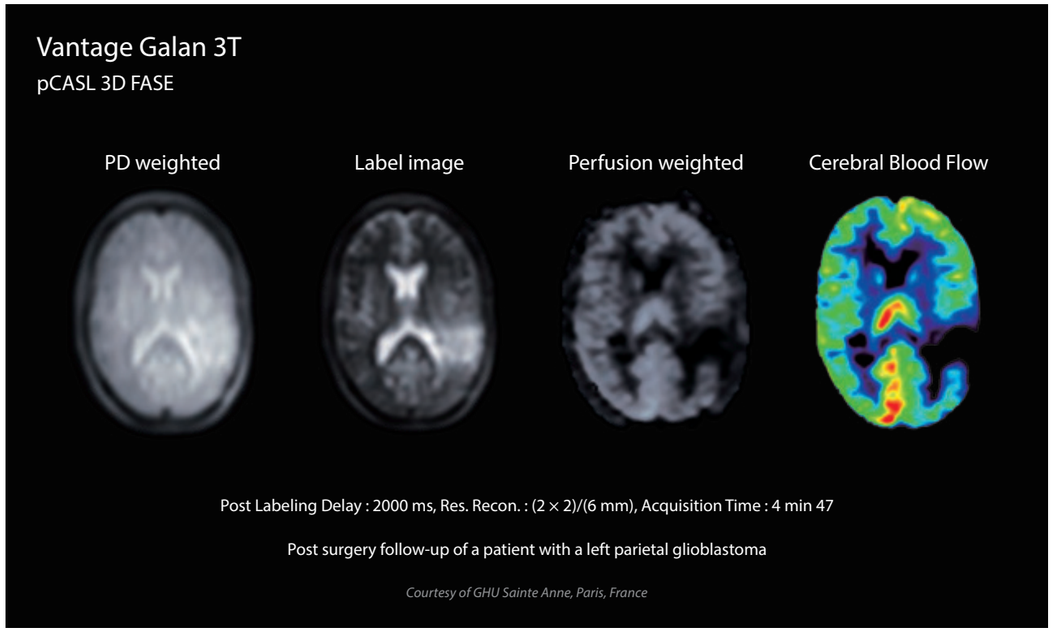
Arterial Spin Labeling

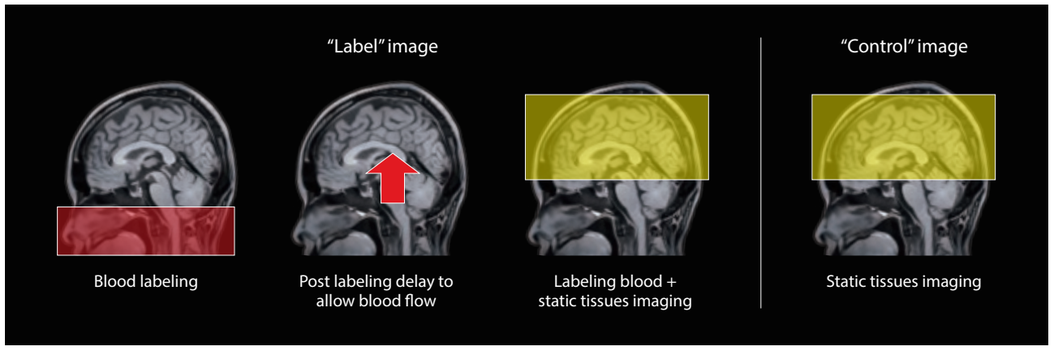
Valentin H. Prevost, Ph.D.

WHAT? Arterial Spin Labeling (ASL) method allows quantitative imaging of blood flow perfusion without the use of external contrast agent.

WHY? The arterial blood used as an endogenous tracer is non-invasive and, due to its physical properties, it represents true tissue perfusion better than external contrast agents can.

WHEN? To study perfusion disorders such as stroke or blood flow alterations induced by cancer, epilepsy, and neurodegenerative diseases.





HOW?

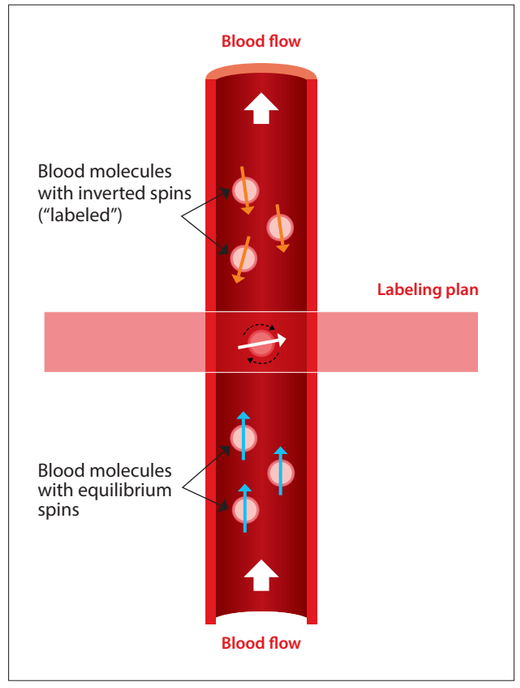
The goal of ASL imaging is to use blood as an endogenous diffusible tracer in order to extract blood perfusion information. To do so, two images are needed. A "label" image is acquired using a labeling plane to invert the magnetization of blood molecules. A post labeling delay allows the perfusion of the tagged blood through tissues. Imaging readout is finally performed in the desired volume to image the labeled blood in addition to static tissues.

Then, a "control" image, without prior labeling of blood, is acquired to image the static tissues of the desired volume. The difference between "label" and "control" images leaves only the signal from arteries delivered to the tissue ("Perfusion weighted" image). Using an equation which implements a PD weighted (PDw) image and several parameters (such as labeling efficiency, label duration, blood T_1), a cerebral blood flow map (Cerebral Blood Flow (CBF) or ASLR) can be generated.

Two main families of ASL techniques exist, based on how blood is labelled:

- **Pulsed ASL (PASL)**: In pulsed ASL, such as ASTAR, the labeling is achieved by using a single short pulse (or a limited number of pulses), with a total duration of few milliseconds, to invert instantaneously a large volume of molecules.
- **Continuous ASL (CASL) and pseudo-Continuous ASL (pCASL)**: In continuous ASL, this labeling occurs over a long period of time (around a second or more), where only blood molecules having crossed a thin labeling plane have their magnetization inverted. Historically, this saturation was performed by a single and continuous saturation pulse (CASL method), but in the most recent approach (pCASL), the saturation is performed using a long train of very short pulses applied every millisecond.

A scientific consensus concluded that pCASL is the recommended ASL method for clinical imaging[1].



Precautions

- Since the CBF map is based on subtracted images, it is sensitive to motion between scans. Therefore, patient motion needs to be minimized as much as possible.
- By definition, ASL methods suffer from a low Signal-to-Noise Ratio (SNR). We recommend to use a low matrix size to get good image quality. Typically, a resolution of 4 × 4 × 6 mm is recommended for a whole brain imaging.
- ASL imaging must be done prior to contrast agent injection. Gd-based contrast agents strongly reduce T_1, deleting differences between "label" and "control" images.

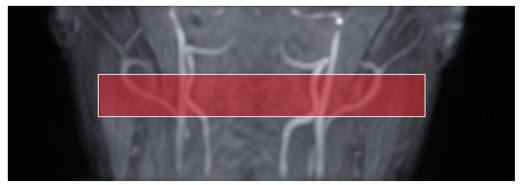
Tips, Tricks and Best Practices

- A field strength of 3T is recommended when available (higher SNR and longer T_1), though satisfactory results can be obtained at 1.5T.
- The use of background suppression is recommended to partially mitigate motion sensitivity.
- FineRecon = ON is recommended for PE/RO directions to improve image resolution.
- Post Labeling Delay needs to be adjusted depending patient age and cardio-vascular function. (children = 1500 ms ; healthy subjects < 70 years old = 1800 ms ; healthy subjects > 70 years old, neonates and adult patients = 2000 ms).

Questions from the field

Q. How should the pCASL labeling plane be positioned?

A. The labeling plane needs to be located in a region where the relevant feeding arteries have large cross sections and are relatively straight. Using an extra Time of Flight scan as a locator image, we recommend to place the labeling plane placed perpendicular to those arteries in order to get the highest signal homogeneity as possible.



Q. What are the differences between the PDw and the control images?

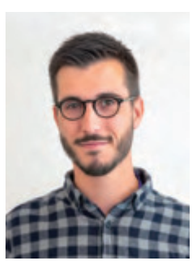
A. PDw image is performed without any pre-saturation pulses. On the other hand, control image uses a saturation scheme that does not label the blood while creating similar magnetization transfer effects that "label" image.

Q. Which are the pCASL advantages compared to ASTAR?

A. The pCASL technique has a higher SNR than ASTAR because of a longer temporal duration of the labeled bolus and because of a higher delivered labeled magnetization.

Q. Which are the pCASL advantages compared to CASL methods?

A. Thanks to the use of larger gradients during RF pulses, pCASL benefits from a better labeling efficiency and less magnetization transfer effects (which can be responsible for subtraction errors between label and control states). In addition, CASL method requires continuous application of RF power, which most current RF amplifiers cannot provide without modification. On the other hand, pCASL is perfectly compatible with all existing clinical scanners. //



Valentin H. Prevost, Ph.D.
MR Clinical Scientist,
Canon Medical Systems Corporation

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Reference
[1] *Alsop et al. Magn Reson Med (2015)*

Moving Forward with Non-Invasive Perfusion Imaging in Clinical Practice

MRI techniques that do not require contrast are advantageous for diagnosis and follow-ups of neurological conditions, especially those in which the use of contrast may be inadvisable, or simply not possible to administer. Arterial Spin Labelling (ASL) is a contrast-free MRI method to measure perfusion that has been used in brain imaging for some time. Canon Medical Systems (herein after Canon Medical) has been working together with clinical experts to enhance this technique further. Dr. Julien Savatovsky, Deputy head of Diagnostic neuroradiology at the Foundation Adolphe de Rothschild Hospital, France, explains what development and improvement of Canon's new pseudo-Continuous ASL (pCASL) sequence brings.

"The A. de Rothschild Foundation Hospital has an extensive neuro-imaging department for diagnosis and treatment of both inpatients and outpatients. Two MR scanners from Canon Medical are used for research and clinical activity, including a Vantage Galan 3T / XGO and a Vantage Orian 1.5T scanner. The department also has a Canon Aquilion ONE / GENESIS Edition CT scanner, and three sonography rooms. Headed by Dr. Savatovsky, the Hospital's Neuroradiology team have worked in a successful research and development partnership with Canon Medical for several years. The partnership has recently focused on exploring the performance of new perfusion sequences."

Arterial Spin Labelling (ASL) MRI provides non-invasive methods to measure tissue perfusion. They can

Dr. Savatovsky reviewing pCASL images at the Foundation Adolphe de Rothschild Hospital in Paris.

"The best advantage of ASL is to allow perfusion assessment without requiring any contrast material at the opposite of DSC (Dynamic Susceptibility Contrast). So it can be beneficial in assessing patients with conditions, such as neurogenerative diseases or seizures, who cannot be injected all the time."

Dr. Julien Savatovsky
Deputy head of Diagnostic neuroradiology at the Foundation Adolphe de Rothschild Hospital

quantify blood flow without the need for invasive contrast agents to enable tissue perfusion to be utilized as a disease and regeneration biomarker. However, historical ASL methods were suffering from a low Signal-to-Noise Ratio (SNR), limiting their clinical use. With the integration of the latest method called pCASL, Canon Medical facilitates the access of ASL in clinical routine.

Advantages of ASL

"The best advantage of ASL is to allow perfusion assessment without requiring any contrast material at the opposite of DSC. So it can be beneficial in assessing patients with conditions, such as neurogenerative diseases or seizures, who cannot be injected all the time," explained Dr. Savatovsky. "In some cases, you cannot perform DSC perfusion, because you cannot or would not want to inject the patient. ASL represents a real benefit for those patients". He added "You can even repeat ASL several times within a day if needed, to compare the results with and without medication for example."

"We usually found similar results between ASL and DSC. However, we have also found that there are few clinical applications in which ASL seems to be more sensitive than DSC," he continued. "For example, in recent seizures, and recent migraines, you see a greater contrast between normal and abnormal site on the ASL perfusion compared to the DSC perfusion."

Potential of pCASL

ASL can be considered as having different modes of operation based on the way to "label" the blood with RF saturations. After having historically developed ASTAR, Canon Medical has focused on developing pseudo-Continuous ASL (pCASL) sequence together with Dr. Savatovsky. His team have 'field-tested' the new sequence and have found that it brings greater image quality than the previous solution.

"The image quality is greater than ASTAR because of a higher SNR and then, a higher resolution (Figure 1). You also have a higher coverage allowing more slices around the brain" he remarked. "And what is interesting is that it seems more reliable in terms of post label delay and sensitivity to slow flows, for example. Usually, you get ASL signal defects in some patients on posterior regions, especially the occipital lobes, but we don't see that much on pCASL compared to other regular stored sequences. Canon Medical made the choice to implement their pCASL product with a spin echo readout. This makes the sequence less sensitive to susceptibility artifact compare to DSC. This is especially appreciated for patients that initially had blood products (e.g. post-operative tumors) or who are suffering from metastases with hemorrhagic transformation. To me, this choice was a key differentiator."

Dr. Savatovsky and his team are researching the boundaries of the new sequence together with Canon Medical.

"We are working towards creating the most optimal protocol for clinical practice," he explained. "Actually, the recommended voxel size is at two millimeters, with still a very high SNR, but we felt that we could even do higher resolution studies, that's why we created a high-resolution protocol at 3T (Figure 1). We think that with a bit of development we could even reach the resolution that we have for DSC perfusion."

"The pCASL image quality is greater than ASTAR because of a higher SNR and then, a higher resolution. You also have a higher coverage allowing more slices around the brain."

Dr. Julien Savatovsky

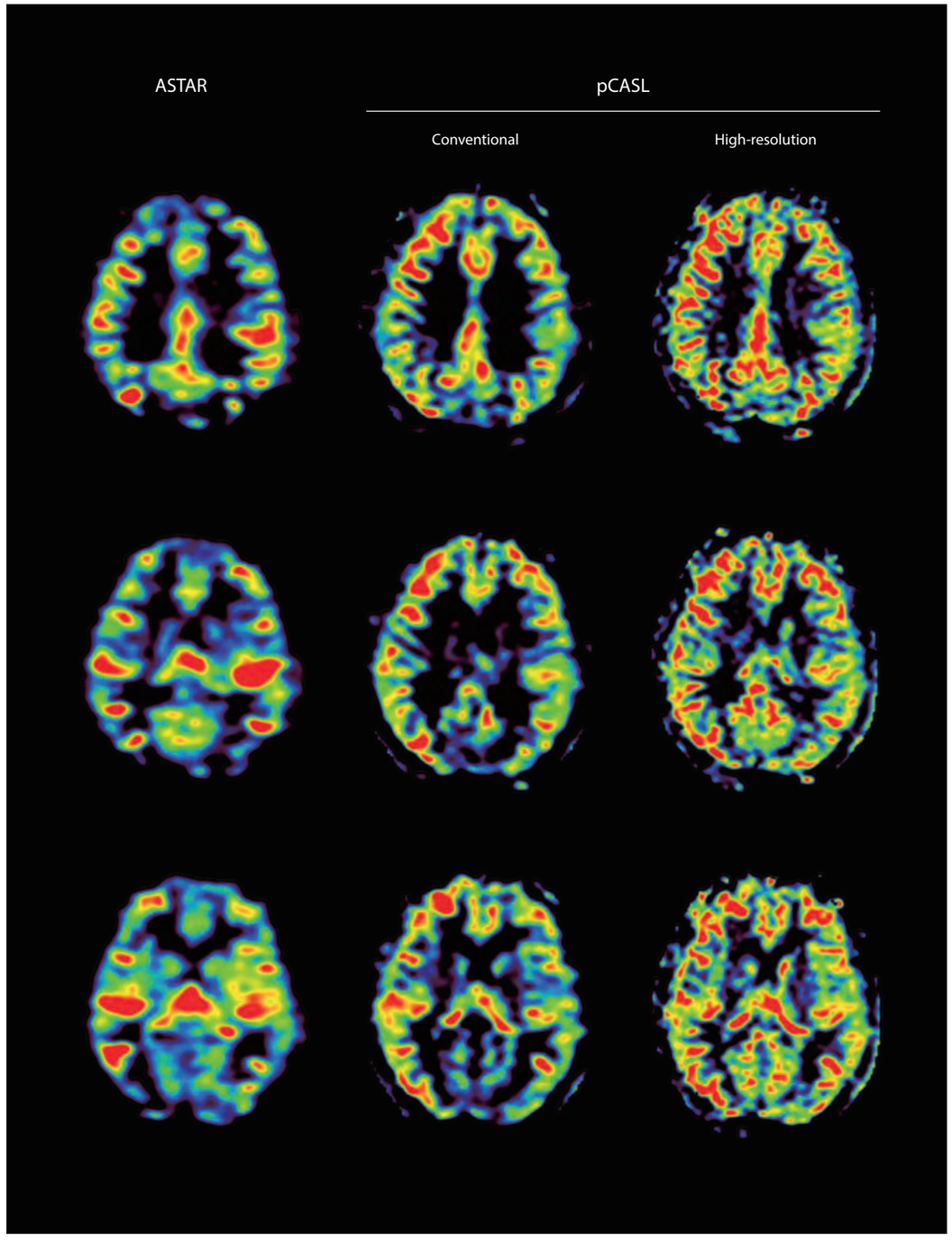

Figure 1: Illustrative Vantage Galan 3T / XGO images with different ASL sequences on a patient suffering from visual acuity loss: previous ASTAR solution compare to the new pCASL solution, with the standard and a high-resolution protocols (Resolution=2×2×6 and 1.5×1.5×5 mm^3 respectively). Higher SNR can be appreciated on pCASL sequences, with a better structure depiction on the high-resolution protocol. No hypoperfusion has been found on this patient.

Dr. Savatovsky with Canon Medical Clinical Scientist, Valentin Prevost.

Partnership in MR research and development

Canon Medical works together with leading clinical and technical experts and institutes across the world in researching new techniques and products. Dr. Savatovsky and the A.de Rothschild Foundation Hospital in Paris, France, is one of its research partners. The Neuroradiology team there undertake retrospective and prospective studies to evaluate new Canon Medical MR products.

Integrated into protocols

The team have already incorporated pCASL and DSC perfusion into their brain perfusion protocols on both their Canon systems, 1.5 and 3T.

"We are already convinced that pCASL fits for a number of clinical indications, and we will continue using it for stroke imaging with normal diffusion, for example, or on any neurological deficits, seizures and recent headaches, as well as for our tumor protocol" (Figure 2). "Obviously, it's not a 'time-saver', because both pCASL and DSC are required, but it helps in clinical confidence. As you have the same information in the two series, but importantly also because the pCASL can reveal additional information, especially in the periphery of the brain, or in areas where you have blood products that makes the DSC perfusion difficult to interpret." //

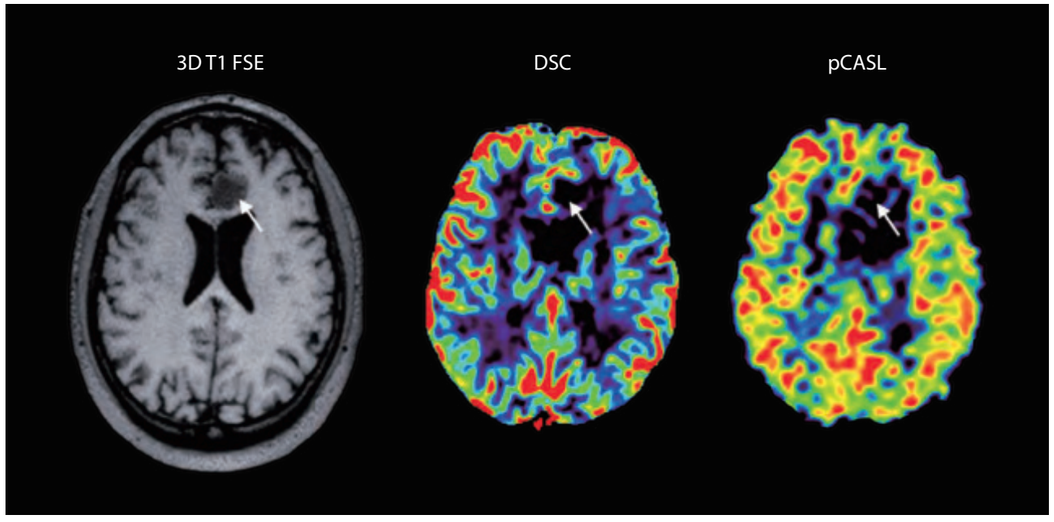

Figure 2: Illustrative 1.5T images with 3D T1 FSE, DSC and pCASL sequence on a patient suffering from a brain tumor, after surgery (white arrows). A left anterior fronto-cingular hypoperfused area can be visualized, corresponding to the tumor resection. Around this cavity, no significant cerebral blood flow increase is detected, excluding the risk for neoangiogenesis. No additional perfusion abnormalities were found in the parenchyma.

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