TOMORROW TODAY

CVWorks

A collection of articles from SIGNA™ Pulse of MR

gehealthcare.com/mr

Table of contents

Karl Vigen, PhD
University of Wisconsin Hospital
Madison, WI

Christopher Francois, MD
University of Wisconsin Hospital
Madison, WI

Cardiac MR in patients with CIEDs

By Karl Vigen, PhD, Senior Scientist, and Christopher Francois, MD, Professor, University of Wisconsin Hospital, Madison, WI

MR imaging volume in patients with Cardiovascular Implantable Electronic Devices (CIEDs) is growing due to the adoption of MR-Conditional devices. Modified cardiac protocols can address common artifacts and distortions resulting from the device, battery or other electronic components, while also complying with MR-Conditional device labeling.

MR imaging was historically contraindicated for patients with CIEDs including pacemakers, implantable cardioverter defibrillators (ICDs), and cardiac resynchronization therapy pacemakers and defibrillators (CRT-P/Ds), due to concerns over possible lead heating, device migration and device malfunction. However, recent CIED development has led to devices with improved resistance to environmental electromagnetic interference, and many recent models have MR-Conditional labeling with approval from regulatory agencies such as the FDA.

As more patients are implanted with MR-Conditional devices, our volumes have grown (see Figure 1) to more than 100 in 2018. The adoption of MR-Conditional implants improves access and the use of MR in these patient subgroups.

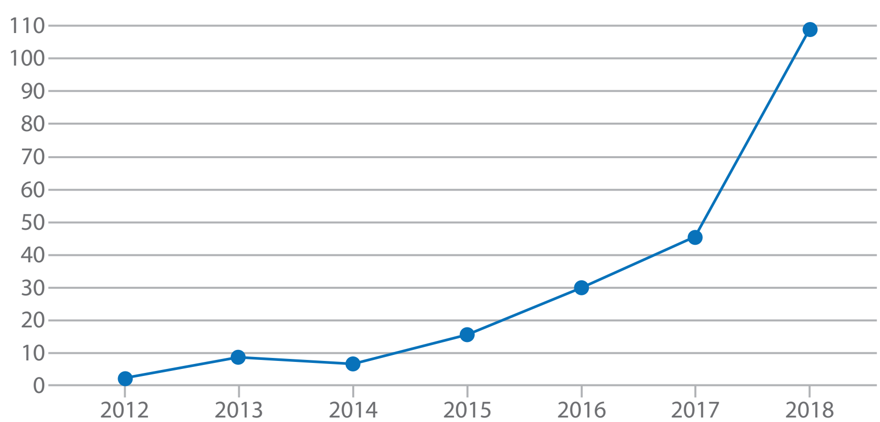


Figure 1. Number of MR exams in patients with MR-Conditional devices, all types (cardiac and non-cardiac) at the University of Wisconsin Hospital.

Due to the location of the CIED generator, most commonly in the left upper chest, distortions in B0 and B1 due to the battery and other electronic components can lead to severe artifacts in cardiac MR (CMR), particularly with ICDs and CRT-Ds. Nearly five years ago, our institution developed a modified CMR protocol for use in patients with CIEDs.

Prior to the imaging exam, a cardiac device nurse programs the patient's device to the pacing parameters corresponding to the device's "MRI mode" or another acceptable mode, as determined by the device clinic team. This is generally a setting such that pacing is off, or a backup mode such that the patient's underlying rhythm is maintained. Occasionally, an asynchronous pacing mode can be used, which paces the patient's heart at a regular rate, and can greatly improve MR image quality compared to an irregular heart rate.

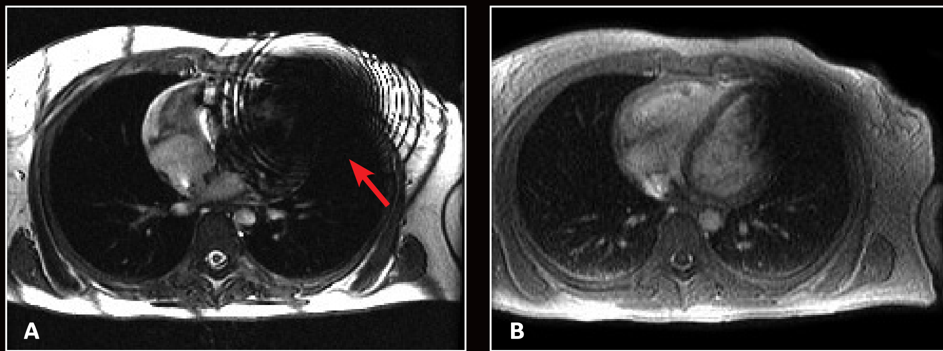


Figure 2. (A) Axial FIESTA. (B) Axial Fast SPGR Cine post-contrast. Note the banding artifact in the FIESTA acquisition.

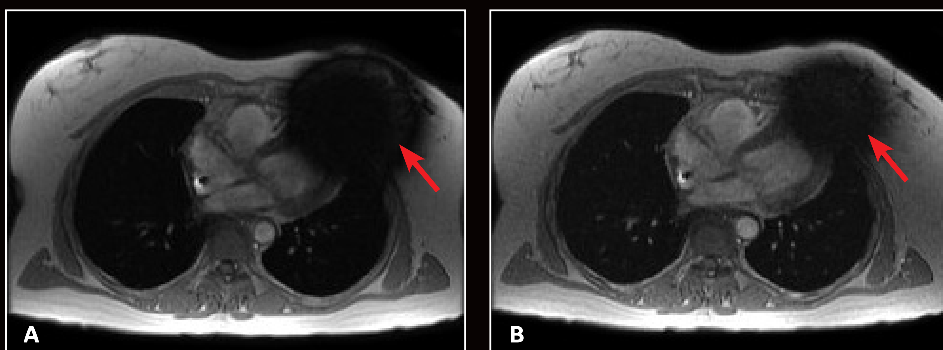


Figure 3. Acquired using Fast SPGR Cine. Comparison of a (A) conventional 8 mm thick/ 0 mm gap slice with a (B) 4 mm thickness and 4 mm spacing to maintain coverage. Note the decrease in artifact with the thinner slice imaging.

Patient positioning in the MR scanner is similar to exams in patients without devices. The patient is connected to a patient monitoring system, so that the patient's ECG and pulse oximetry information can be monitored throughout the exam. In addition, we attempt to have the patient place their arms over their head, as this can move the device away from the imaging field-of-view (FOV) and reduce the amount of main magnetic field (B0) modulation near the imaging FOV.

FIESTA imaging sequences can contain banding artifacts due to B0 field modulations; the artifacts can be particularly troubling due to the intense B0 modulation caused by the CIED. These artifacts are usually more severe with ICDs compared to pacemakers. By using a Fast SPGR Cine imaging sequence, the banding artifacts can be removed, albeit with a reduction of blood-to-myocardium contrast-to-noise ratio (CNR). Acquiring the short- and long-axis Fast SPGR Cine images following contrast agent administration can improve CNR, and has the additional benefit of decreasing total exam time (since there is normally 10 minutes of waiting following contrast agent administration). Figure 2 shows a typical image acquired with FIESTA (2A) and post-contrast Fast SPGR Cine (2B) in a patient with an ICD.

Using thinner slices to reduce through-slice dephasing can also help reduce artifact. In Figure 3A, a more conventional 8 mm thick/0 mm gap slice was used with Axial post-contrast Fast SPGR Cine; in Figure 3B, a slice at the same location with 4 mm thickness and 4 mm spacing to maintain coverage with fewer artifacts was utilized. Disadvantages include increased TE with reduced slice thickness and reduced SNR, although the CNR between blood and myocardium can be improved if acquired post-contrast.

For late gadolinium enhanced (LGE)/ myocardial delayed enhancement (MDE) imaging, an inversion pulse with an appropriate TI is used to suppress signal from normal myocardium, highlighting signal from infarcted myocardium. With conventional MDE imaging, B0 inhomogeneity could cause incomplete inversion and artifactual high signal in normal myocardium could be mistaken for infarction. A new wide-bandwidth adiabatic inversion pulse for MDE (standard in GE's DV26.0 software) allows suppression of myocardial signal without artifactual high signal (see clinical cases). When combined with the Phase-Sensitive Inversion Recovery (PSIR) option, high image quality can be

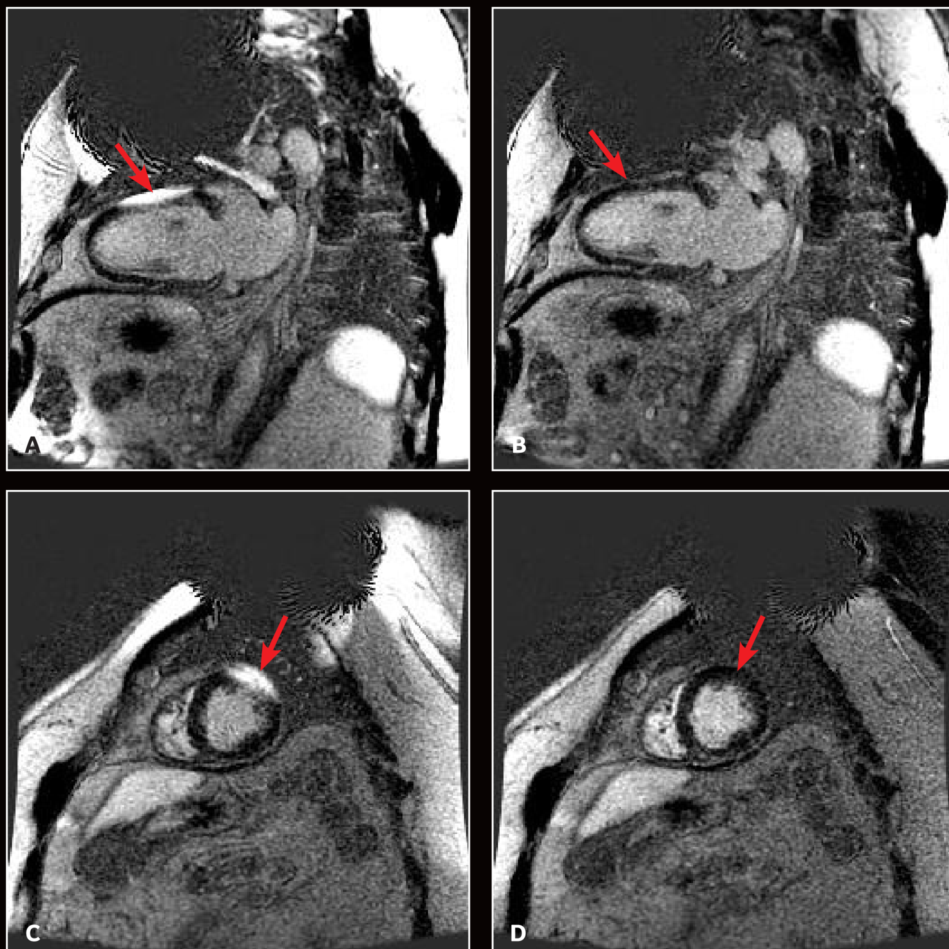


Figure 4. Comparison of (A, C) original inversion vs (B, D) higher broadband inversion, using the PSIR option. Note the improved image quality when improved broadband inversion was utilized.

achieved (Figure 4). We do not use the single-shot MDE sequence (SS MDE) at 1.5T for these patients, since this uses a FIESTA readout combined with parallel imaging; the combination is prone to artifactual high late enhancing signal.

We image all MR-Conditional CIED patients at 1.5T, with SAR and dB/dT set to Normal Operating Mode, which has a whole body SAR limit of 2.0 W/kg. Recent versions of GE software include a Low SAR mode, allowing the user to specify even lower limits for SAR or B1+RMS. Most MR-Conditional CIEDs specify 2.0 W/kg for SAR at 1.5T; however, those that are MR-Conditional at 3.0T can have lower limits. For example, the Medtronic Advisa DR/SR MRI pacemakers specify maximum B1+RMS=2.8μT for thoracic imaging, which can be easily set in Low SAR mode. The availability of 3.0T imaging combined with low SAR mode is expected to be important if the scan is clinically indicated for 3.0T (e.g., PET/MR) or for institutions without access to a 1.5T system.

Currently, all patients with MR-Conditional CEIDs are scanned on a wide bore 1.5T MR system in our facility, assuming specifications for field strength and maximum spatial gradients of the static field in the MR-Conditional device labeling can be met. We find the wider bore is particularly helpful when imaging patients who cannot easily hold their arms above their head. Additionally, employing rapid sequences may reduce scan times and enhance patient comfort and compliance; however, our institution has not yet evaluated rapid sequences for CMR imaging in patients with MR-Conditional devices.

Recently, GE introduced lightweight AIR™ Coils. While we have not had an opportunity to use the AIR™ Coils for imaging patients with CIEDs, our current experience for cardiac imaging on our 3.0T SIGNA™ Premier systems demonstrate excellent image quality. We anticipate improved patient comfort for these exams, which may facilitate improved compliance for arms-above-head positioning.

Case 1

Patient with a history of dilated cardiomyopathy and worsening ejection fraction; pacing dependent. With MR, the left atrium and left ventricle were shown to be mildly dilated. Global hypokinesis was seen with regional variation specifically with focal hypokinesis/dyskinesis in the mid/apical septal and apical anterior segments. There is curvilinear late gadolinium enhancement consistent with scarring in the basal-anterior septal mid myocardium.

Optima™ MR450w

PARAMETERS

	Sagittal short axis Fast SPGR Cine	*Axial long axis Fast SPGR Cine*	*Sagittal short axis PS MDE*	*Coronal and Axial long axis PS MDE*
TR (ms):	6.3	6.3	8.2	7.9
TE (ms):	2.6	2.6	3.9	3.8
FOV (cm):	38 x 38	38 x 29.3	38 x 26.6	38 x 30.4
Slice thickness (mm):	6	6	6	5
Frequency:	256	256	224	200
Phase:	160	160	192	192
NEX:	1	1	1	1
Scan time (min):	1:30 (12 slices)	0:25 (sec.) (3 slices)	1:48 (12 slices)	0:42 (sec.) (4 slices)

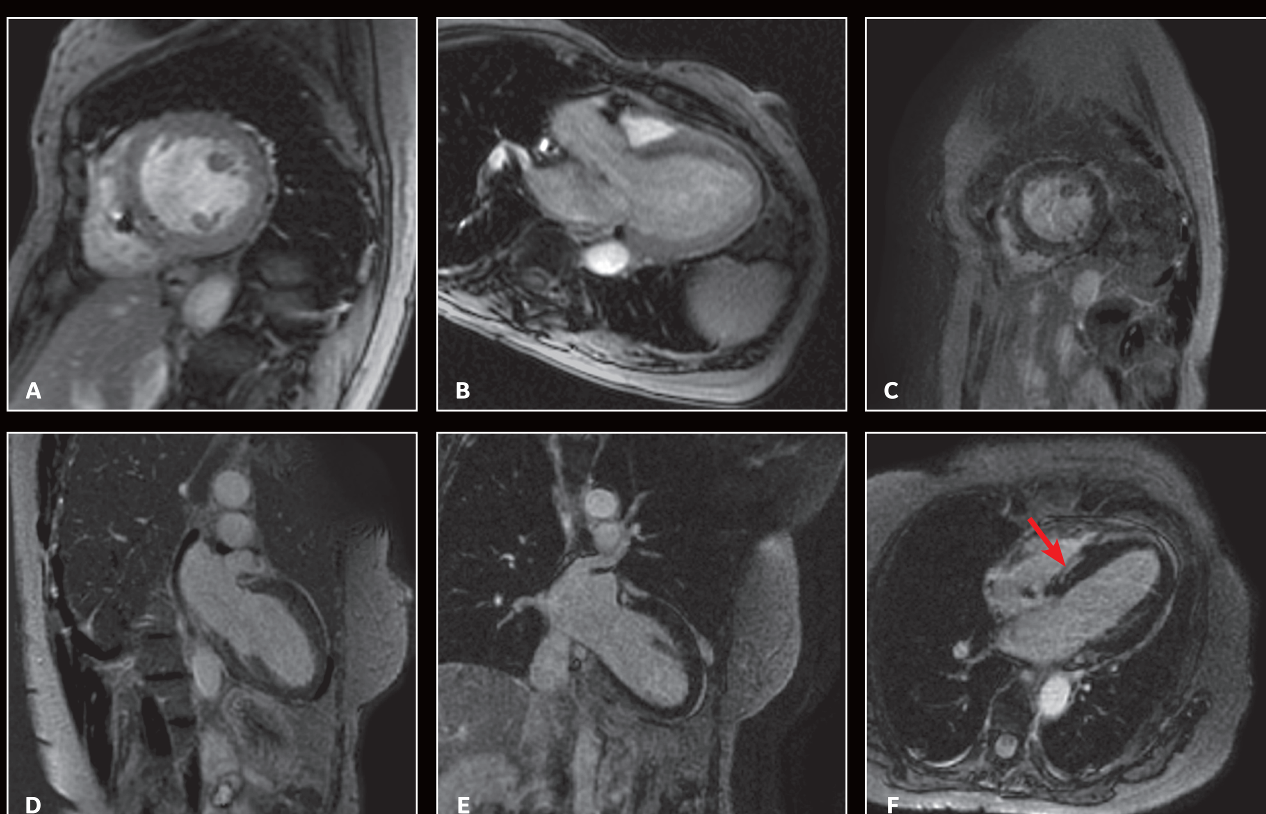


Figure 5. (A) Short axis Fast SPGR Cine; (B) long axis Fast SPGR Cine; (C) short axis MDE (arrow); (D-F) long axis MDE.

Case 2

Patient with a history of ventricular tachycardia with possible left ventricular thrombus. MR shows enlarged left ventricle, with global hypokinesis with dyskinesis in the apical anterior wall and true apex. Thrombus is seen in the apex, with a thin rim of increased enhancement at the edges of the thrombus. There is subendocardial to transmural enhancement in the apex. Ⓢ

Optima™ MR450w

PARAMETERS

	Coronal short axis Fast SPGR Cine	*Axial long axis Fast SPGR Cine*	*Long axis PS MDE*
TR (ms):	5.3	5.3	5.9
TE (ms):	2.4	2.4	2.8
FOV (cm):	40	40	40
Slice thickness (mm):	6	6	6
Frequency:	192	192	192
Phase:	160	160	192
NEX:	1	1	1
Scan time (min):	1:21 (12 slices)	0:20 (sec.) (3 slices)	0:49 (sec.) (3 slices)

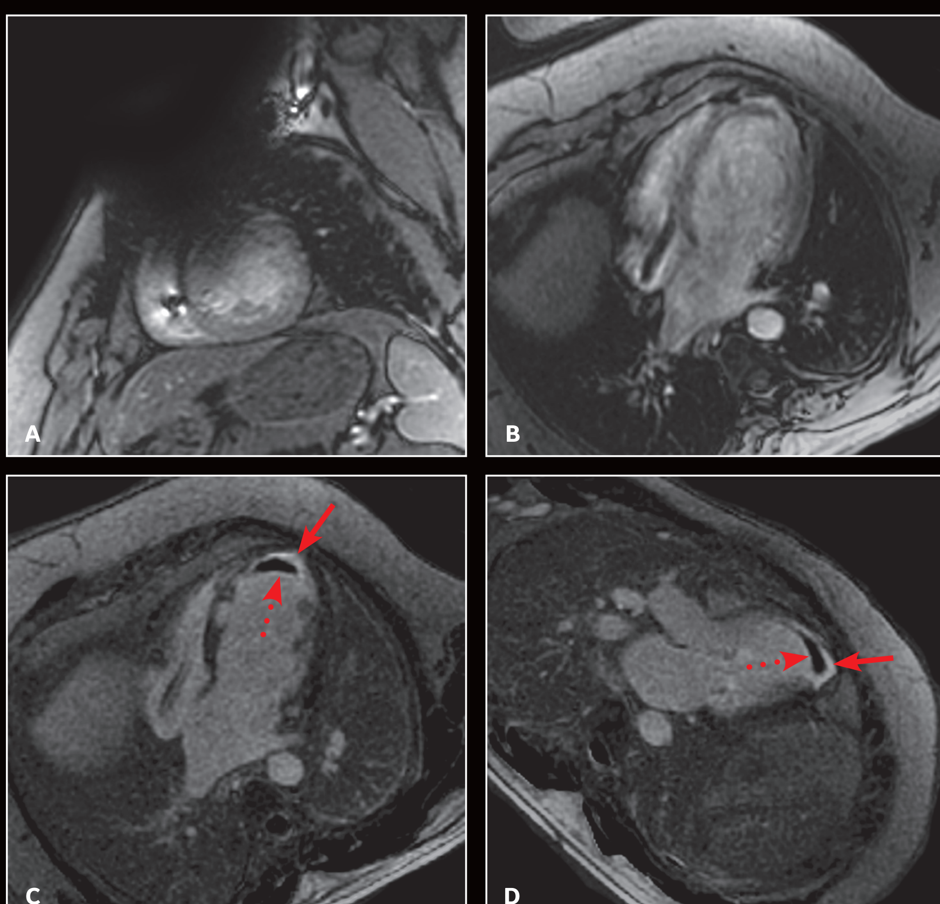


Figure 6. (A) Short axis Fast SPGR Cine; (B) long axis Fast SPGR Cine; (C-D) phase-sensitive long axis LGE.

Edwin Oei, MD, PhD
Erasmus Medical Center
Rotterdam, Netherlands

Alexander Hirsch, MD
Erasmus Medical Center
Rotterdam, Netherlands

AIR: a brilliant improvement in high-quality imaging and patient comfort

As one of the first sites in the world to install SIGNA™ Premier and AIR™, Erasmus Medical Center is a leader in adopting cutting-edge technologies. These new solutions are providing a better patient experience while delivering high-quality imaging and advanced applications, further enhancing the excellent care provided by clinicians at Erasmus.

Erasmus Medical Center in Rotterdam, Netherlands, is a leading university medical center in Europe and has long been recognized for its adoption of cutting-edge technologies and advanced medical solutions. For the last few years, Erasmus has collaborated with GE Healthcare to evaluate the introduction of new technologies into the clinical environment. One of these is AIR™.

AIR™ Coils are designed to fit all patients, allow flexibility in any direction and closely wrap around the patient's anatomy for greater visibility of hard-to-scan areas with excellent image quality. By conforming to the patient habitus and bringing the coil elements closer to the patient, AIR™ improves signal quality and signal-to-noise ratio (SNR) and reduces imaging artifacts when compared to previous generations of conventional coil technology.

Recently, several clinicians from Erasmus shared their initial impression of AIR™ on the SIGNA™ Premier 3.0T MR system, including the AIR™ Anterior Array (AA) Coil, the AIR™ 48-channel Head Coil and AIR Touch™.

Cardiac imaging

Alexander Hirsch, MD, cardiologist, specializes in non-invasive cardiac imaging. In cardiac patients, Dr. Hirsch scans cardiomyopathy and ischemic heart disease patients on SIGNA™ Premier. Typically, the 2D FIESTA, first-pass perfusion and MDE images are the most common sequences for these patients. Image quality is important, particularly in the late enhancement (MDE) sequence where Dr. Hirsch evaluates myocardial viability. With the 2D FIESTA sequence, he is looking at cardiac function. However, 2D FIESTA sequences have historically been problematic at 3.0T.

"The new SIGNA™ Premier system is especially good for late enhancement images and also for perfusion," Dr. Hirsch says. "I was able to see the anatomy and the function, as well as differentiate the contrast between the blood and the myocardium. Previously in a 3.0T system, that was a problem, however, with the SIGNA™ Premier this has improved a lot."

A key factor in the improved image quality is AIR™. Dr. Hirsch says he gets a more homogeneous signal and better contrast between the blood and the myocardium.

Juan Hernandez Tamames, PhD

Erasmus Medical Center
Rotterdam, Netherlands

Watch Dr. Hirsch's 2019 SCMR presentation, "Getting consistent and quantifiable results in cardiac imaging:" https://youtu.be/dQ3-sU-kPv0

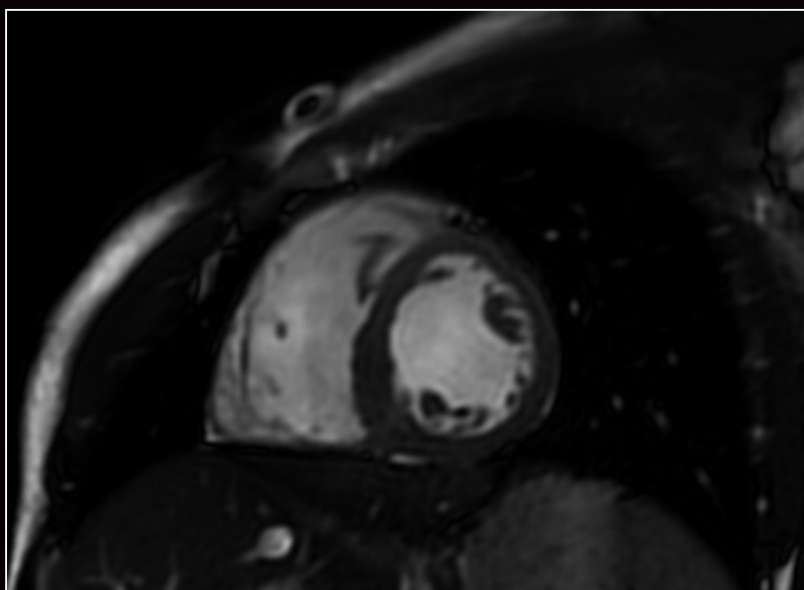


Figure 1. Short axis 2D FIESTA. The combination of SIGNA™ Premier and AIR™ delivers high SNR and high image quality for excellent cardiac MR imaging results at 3.0T.

"Because of the specialized nature of our facility, with referrals from all over the Netherlands, it is important to have the latest technology," he says. "With the new GE SIGNA™ Premier and AIR™, we can provide high- quality care for our patients."

"The new AIR™ AA Coil has a major advantage in that it helps provide high image quality," Dr. Hirsch adds. Plus, with SIGNA™ Premier he has been able to achieve high SNR, which is very important for the sequences he is using. Dr. Hirsch also expects to see improvements in 4D Flow (ViosWorks), as well as the new 3D MDE sequence.

"When we started working with SIGNA™ Premier, I was pleasantly surprised to see the image quality, especially for the 2D FIESTA sequence," he says.

Brendan Bakker, MR radiographer, has developed cardiac MR (CMR) protocols at Erasmus with Dr. Hirsch. While 1.5T was typically preferred for CMR, he worked with Dr. Hirsch to evaluate CMR exams on the SIGNA™ Premier 3.0T MR system with AIR™.

"The AIR™ AA Coil is brilliant and it's an improvement for the patient. It is very easy to handle, very lightweight and the quality is very good for cardiac imaging, especially on the SIGNA™ Premier system," Bakker says.

"The AIR™ AA Coil is very flexible, you can put it around the chest or stomach but also use it around the knee or shoulders," Bakker says. "With other coils that are more rigid, this is not possible."

In pediatric imaging, the AIR™ Coils fit almost like a blanket on the child, he adds.

MSK imaging

Edwin Oei, MD, PhD, is an Associate Professor of Musculoskeletal Imaging and Section Chief of Musculoskeletal Radiology at Erasmus Medical Center. He dedicates half his time to research and working with MR physicists and PhD students to improve technologies and apply MR imaging in population health studies.

"SIGNA™ Premier offers advantages in musculoskeletal imaging because of its

Brendan Bakker
Erasmus Medical Center
Rotterdam, Netherlands

Jean Paul Laarhoven
Erasmus Medical Center
Rotterdam, Netherlands

higher gradient performance, especially when it is used with the AIR™ Coil," Professor Oei says.

According to Professor Oei, musculoskeletal (MSK) MR imaging tends to suffer from artifacts and movement more than in other body parts. Often, there are difficulties with positioning patients due to their injury or ailment, as well as using the right coil. While coil selection is not as problematic in the knee or ankle, it can be more difficult when imaging the shoulder, wrists or ribs.

"With AIR™, we are more flexible in choosing the coil, which allows for imaging specific body parts with greater accuracy. For patients with chronic diseases such as arthritis, it may not be easy for them to lie still in the scanner for a long time with a rigid coil. The AIR™ Coil is lighter and more comfortable for the patient so, indirectly, I think it will also reduce movement artifacts."

Professor Edwin Oei

AIR™ also assists with patient positioning. When using traditional rigid coils, the body part being imaged had to be positioned precisely in the coil. With AIR™, this is less of an issue.

"We mainly now use the blanket-type AA Coil and have achieved great imaging results in the chest wall and in joints," adds Professor Oei. "I think AIR™ is beneficial for diverse patient groups, including pediatric and elderly patients."

Professor Oei believes there is a movement in MR imaging toward whole-body imaging, particularly for oncology. He anticipates that AIR™ will provide excellent results over existing coil technology due to its wide coverage.

"Since the introduction of SIGNA™ Premier and AIR™ at Erasmus, I've seen image quality improve over previous scans and I believe that AIR™ can greatly improve patient throughput," Professor Oei says.

The AIR™ family of products also includes a 48-channel Head Coil. Jean Paul Laarhoven, MR radiographer, has scanned patients with both the AIR™ 48-channel Head Coil and the AIR™ AA Coil on SIGNA™ Premier. With the ability to adjust the coil for larger-sized heads and necks, he can accommodate more patients. He has found that patients with anxiety or claustrophobia can better tolerate the AIR™ 48-channel Head Coil because the front part of the coil is slightly smaller and doesn't cover the patient's entire face.

"You can immediately see the high-quality images that the AIR™ Coil captures," Laarhoven explains. "Of course, we also have the Posterior Array (PA) in the table so we only have to position the AIR™ AA Coil on top of the patient."

Improving the patient experience

Sita Ramman has been an MR radiographer for nearly 28 years at Erasmus. Often, she has had to comfort and reassure patients who are nervous about their MR exams. She will explain that they have to remain very still and may have to hold their breath while the system acquires the images.

Since the introduction of AIR™, she has seen a noticeable difference.

"The patients like the AIR™ Coils because they are very lightweight and flexible, and mold to the patient's anatomy," Ramman says. "For us, it is very easy to position. You just put it on the patient and that's it. That's all you have to do."

She has also used AIR Touch™, an intelligent coil localization and selection tool that enables automatic coil element selection and uniquely optimizes uniformity and SNR. AIR Touch™ informs the system when the coil is connected, allows the technologist to landmark the patient with a single touch and even optimizes the element configuration. Coil coverage, uniformity and parallel imaging acceleration are generated dynamically to optimize image quality. A simplified user interface allows the technologist to focus on the patient and also maximizes examination efficiency.

Sita Ramman

Erasmus Medical Center
Rotterdam, Netherlands

Figure 2. AIR™ Coils are flexible and assist with patient positioning in areas where coil selection may be more difficult, such as the wrist. (A) Coronal 3D MERGE; (B) Coronal PD FatSat; and (C) Coronal T2 Flex.

"We just put the AIR™ Coil on the patient, localize using the AIR Touch™ button on the table and move the patient inside the SIGNA™ Premier," Ramman explains. "With AIR™ Coils and AIR Touch™, we don't need to do any calibration as it is done automatically. This makes a difference in our daily routine because it takes less time to position a patient."

A remarkable advance

Juan Hernandez Tamames, PhD, Associate Professor (MR) and Head of the MR Physics group in the radiology department at Erasmus, facilitates the introduction of new technology in MR imaging for both clinical and research purposes.

"SIGNA™ Premier incorporates several new approaches and breakthroughs in technology," Professor Tamames says. "For example, the AIR™ Coils are one of the most remarkable innovations I've seen because they increase SNR."

He also discovered that the HyperBand capability on SIGNA™ Premier enables the possibility to simultaneously scan several slices, accelerating acquisition with the potential to shorten scan times when using DWI. With the parallel transmission, he can tailor the RF for specific tissues in a more appropriate way.

"Compressed sensing is another remarkable advance on SIGNA™ Premier," Professor Tamames adds. "When used with the AIR Coil™, which improves signal due to the closer proximity to the patient anatomy and tissue, we can increase the acceleration with compressed sensing and parallel imaging to reduce scan times."

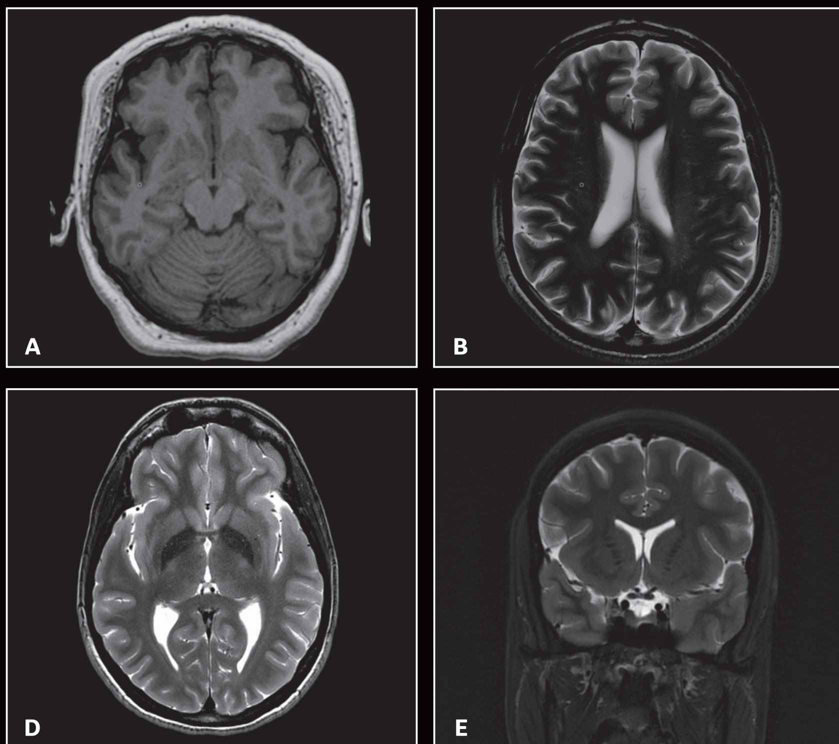


Figure 3. The AIR™ 48-channel Head Coil delivers more signal from the cortical, basal ganglia and deep brain. (A) Axial 3D T1 FSPGR; (B) Axial T2; (C) Axial DWI b1000; (D) Axial T2 PROPELLER; and (E) Coronal T2 PROPELLER FatSat.

For example, since the lungs are filled with air, it is often difficult to obtain good SNR. Because the AIR™ AA Coil lays on the patient's chest, it is as close to the body as possible. This enables a high SNR.

Another advantage is in pediatric imaging. Professor Tamames says a baby can be wrapped in the coil, which makes them more comfortable and enables the coil to get closer to the anatomy.

"In general, the AIR™ Coil is more convenient and it can fit almost any sized anatomy," adds Professor Tamames.

Professor Tamames is interested in testing the AIR™ AA Coil with a conventional head coil and also with the AIR™ 48-channel Head Coil.

"With 48-channels we can accelerate more because we have a really good, high-quality signal," Professor Tamames explains. "By accelerating, we reduce the echo time, which means less distortion in an EPI sequence. And that is important for exploring the basal ganglia and frontal or temporal areas. Not only is the signal better, but the anatomy and morphology of the tissue is more realistic."

Watch the team at Erasmus discuss their experience with AIR™.
https://youtu.be/MeGebBSjUNQ

Matthew T. Bramlet, MD
Children's Hospital of Illinois,
Peoria, IL

An efficient and reproducible toolset for cardiac MR image analysis

Recent advances in cardiac MR imaging and post-processing capabilities, such as higher spatial-temporal resolution and accelerated cardiac exam workflows, have reinvigorated its use in clinical practice.

To address this growing need, GE Healthcare announced the integration of cvi42 cardiovascular post-processing software, licensed from Circle Cardiovascular Imaging (Calgary, Alberta, Canada), onto its GE Advantage Workstation (AW) and AW Server. cvi42 is state-of-the-art software that delivers a comprehensive toolset for cardiovascular MR image analysis, including features such as automated contour definition, quick-editing tools and synchronized viewing schemes that simplify tasks commonly done manually. It contains a broad suite of advanced, easy-to-use modules for viewing and analyzing cardiac MR images, including heart function, flow, tissue characterization and T1 mapping and tissue parametric mapping (T2/T2*).

Matthew T. Bramlet, MD, the Director of Congenital Cardiac MRI at Children's Hospital of Illinois and an Assistant Professor of Pediatrics at the University of Illinois College of Medicine at Peoria, has been using cvi42 as his cardiac MR post-processing software tool for several years. As a pediatric cardiologist, he specializes in children with congenital heart disease, a disease present at birth where structural heart defects involving the heart muscle, valves and/or associated arteries and veins disrupt the normal flow of blood through the heart. For example, blood can flow in the wrong direction or to the wrong place, with varying impact to the patient's health depending on the severity of blood flow disruption. Accurately measuring heart morphology and blood flow is critical for proper diagnosis and treatment planning of congenital heart disease.

Fortunately, since the human cardiovascular system is a closed system of heart and blood vessels, certain cardiovascular relationships must hold true, which offers the possibility of internal validation when performing volume and flow measurements—in other words, the "numbers must match."

"cvi42 is valuable because it is an efficient and reproducible tool that allows me to standardize how to validate the numbers I provide in my reports," Dr. Bramlet says.

> "When calculating left and right ventricle numbers, I want to have greater confidence in the volumetric analysis and diastolic volumes. By using a reproducible tool, I'm confident that my numbers match."
>
> *Dr. Matthew Bramlet*

In particular, the thresholding segmentation contouring tool in cvi42 is easy to use on congenital exams with a quick click-n-drag mouse action that facilitates his ability to achieve the same level of thresholding in each imaging slice, and therefore generates reproducible values. With cvi42, Dr. Bramlet can apply the threshold and have a high level of confidence that the values are accurate on each slice.

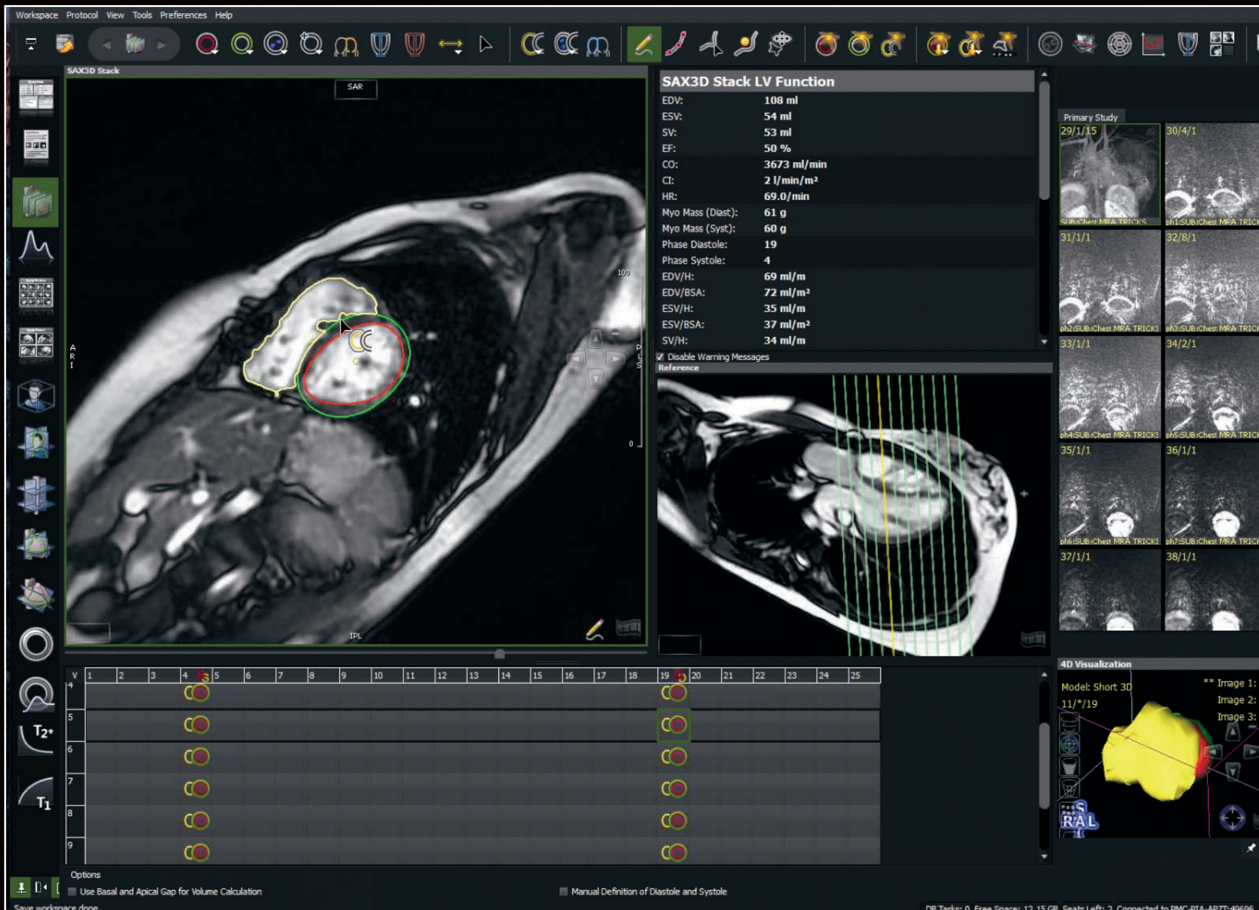


Figure 1. Patient with Tetralogy of Fallot: (A) Using a volumetric short axis cardiac MR image, the clinician can draw the contours of the end-diastolic and end-systolic phases.

When tracking the endomyocardial border, it is possible to lose the border when a ventricular trabeculation and compaction comes together. Yet, with the thresholding tool, Dr. Bramlet says he can "dive down into where the endocardium is located in a unified fashion, based on minor variations and signal intensity, and feel more confident visually when looking at ejection fraction and the right ventricle that it matches the left ventricle."

In cases of Tetralogy of Fallot, a common congenital anomaly, Dr. Bramlet uses the software to quantify right heart flow and volume. The regurgitant flow fraction measured at the pulmonary valve should match the left and right ventricular volumes. When these numbers do match, he is then confident providing the value to the surgical team for their decision-making process.

As an example, in the case of a 5-year-old patient with pulmonary regurgitation and volume overload on the right ventricle, he uses cvi42 to calculate the end-diastolic right ventricular volume just before systole. This value is often used by institutions to determine when a patient should undergo pulmonary valve replacement surgery.

"I want to derive that volume not just from a single analysis but one that is validated elsewhere in the patient imaging data," Dr. Bramlet says. "In a typical patient study, in addition to the right and left ventricular analysis, I will include aortic and pulmonary phase contrast sequences, which allow me to correlate these values. The regurgitant fraction from the pulmonary valve will frequently relate to the left ventricle and right ventricle. When these values match up, then I am more confident it is a true representation."

Dr. Bramlet finds cvi42 is not only easier and more reproducible, but it is also faster with more reliable values.

"cvi42 values are consistent with the clinical picture and easy and efficient to obtain," Dr. Bramlet adds.

Figure 2. Patient with Tetralogy of Fallot: The flow values are important in patients with coarctation of the aorta. Selecting the ascending and descending aorta generates additional data that can be used as an internal control to validate the flow data.

In clinical practice, Dr. Bramlet will first launch the 4D viewer for an overview of the case and the volumetric display. He uses the subtracted series from TRICKS and selects a time-resolved image to render (Figure 1). Next, he finds a third subtraction series, and loads the right side of the heart structures for an ideal representation of the organ. He then processes a 3D volumetric map for visualization purposes only (no measurements) and creates a rotating cine image.

> "The tools (in cvi42) allow me to move faster through the slices and image series, and facilitate movement and actions during the data manipulation so that it is more reliable. I measure the descending aorta every time for extra confidence and by doing that I feel I've gained more knowledge on the patient's condition."

Dr. Matthew Bramlet

Darryl Sneag, MD
The Hospital for Special Surgery
New York, New York

Hollis Potter, MD
The Hospital for Special Surgery
New York, New York

A new era of deep-learning image reconstruction

Radiologists and technologists are intimately familiar with the traditional compromise in MR between image quality and scan time. Higher image quality — through higher SNR and/or spatial resolution needed to resolve anatomical detail — necessitates long scan times, whereas faster scans — desired for patient comfort and productivity — compromise image quality and diagnostic confidence. AIR™ Recon DL‡, an innovative new reconstruction technology from GE Healthcare based on deep learning, offers a fundamental shift in this balance between image quality and scan time, resulting in TrueFidelity™ MR images that elevate the science of image reconstruction for clinical excellence without conventional compromises.

Conventional MR image reconstruction gives rise to well-known image artifacts as a direct result of the data acquisition and reconstruction process. For example, thermal and electrical noise during data sampling translates into random image noise that reduces SNR, while incomplete sampling of high spatial frequencies creates partial volume and edge ringing (i.e., Gibbs ringing) artifacts in the final reconstructed image.

Traditional methods to address these artifacts include hardware, software and acquisition approaches. Hardware solutions such as higher field strength magnets and more RF coil elements can improve SNR. Software filters are commonly applied in the data reconstruction pipeline to mitigate noise and ringing; however, these are only partially effective and can have the undesired impact of reducing effective spatial resolution. In the acquisition protocol, scan parameters can be adjusted to improve image quality, but this comes at a high cost. For example, SNR can be improved by increasing the number of signal averages (NEX) with a proportional increase in scan time; truncation artifacts can be mitigated by increasing spatial resolution, which in turn typically increases scan time and also reduces SNR. This costly SNR/spatial resolution/scan time interdependency forces clinicians to make difficult trade-offs between image quality and scan time for a given patient and clinical need.

Though there has been some success easing this MR trade-off with existing technologies, the reality is that many images today still suffer from low SNR and artifacts, which can lead to decreased diagnostic confidence and reduced radiologist productivity. Patients may be called back for re-scans, which leads to fewer daily scan slots available for scheduling new patients. It can also lead to lower patient throughput due to repeated scans during the exam, further backlogging the schedule and leading to a poorer patient experience.

‡510(k) pending at the US FDA. Not yet CE marked. Not available for sale.

Pascal Roux, MD

Centre Cardiologique du Nord
Paris, France

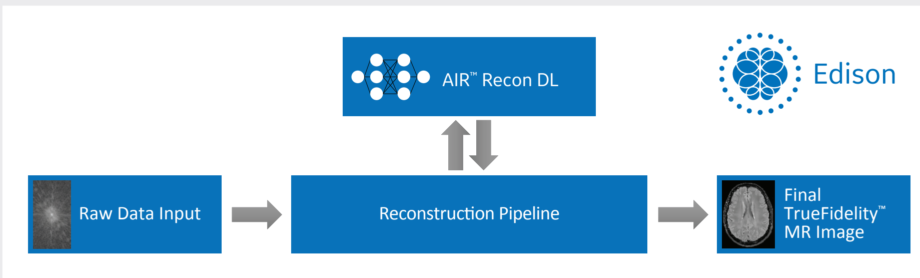


Figure 1. AIR™ Recon DL is integrated directly into the MR image reconstruction pipeline to intelligently reconstruct a final image with high SNR and sharpness.

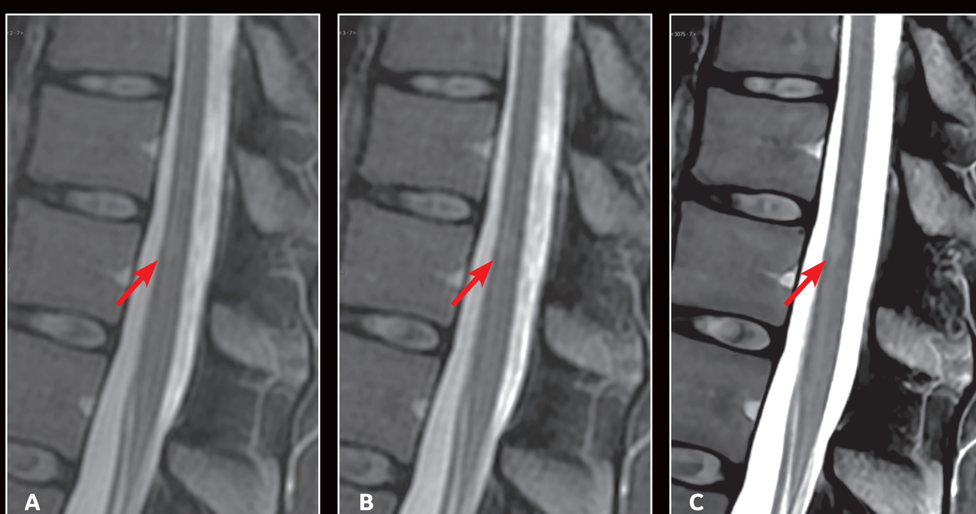


Figure 2. AIR™ Recon DL improves SNR to help depict lesions. (A) Existing protocol: sagittal T2 FSE, 0.9 x 1.0 x 3.5 mm, 4 NEX, 2:50 min. (B) Revised protocol: sagittal T2 FSE, 0.9 x 1.0 x 3.5 mm, 2 NEX, 1:28 min. (C) Image in 2B reconstructed with AIR™ Recon DL at maximum noise reduction to enable shorter scan time without sacrificing SNR.

Images courtesy of CCN

Artificial intelligence now offers an exciting new means to mitigate traditional image artifacts and generate clearer, higher-quality images than previously obtainable from the same MR data.

AIR™ Recon DL represents a revolution in MR image reconstruction by introducing a deep learning-based convolutional neural network to intelligently reconstruct a final MR image with high SNR and image sharpness. AIR™ Recon DL is not a post-processing technique but rather is embedded directly in the reconstruction pipeline, where the neural network model is applied to acquired input data to remove noise and ringing artifacts prior to final image formation (Figure 1). By operating on raw data within the online reconstruction pipeline, AIR™ Recon DL benefits from access to the full set of acquired source data to generate an image, compared to post DICOM image conversion where important information has been lost.

AIR™ Recon DL uses a feed-forward deep convolutional neural network trained on over 10,000 images using GE's Edison AI Platform. Supervised learning was performed by using data pairs of high SNR, high-resolution images and low-SNR, low-resolution images. The trained network employs a cascade of over 100,000 unique filters that recognize patterns characteristic of noise and low resolution to reconstruct only the ideal object image. The network

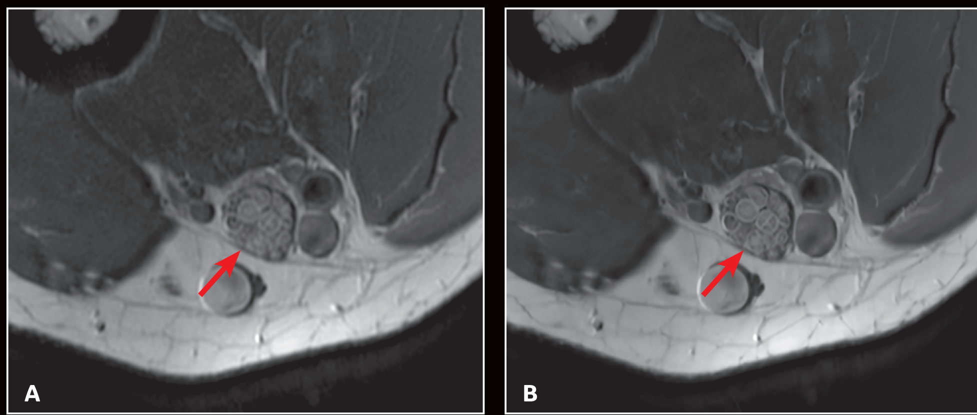


Figure 3. Spontaneous median neuropathy of the elbow. Axial PD 2D FSE. (A) Image acquired with standard protocol, 512 x 352, 12 cm FOV, 2 NEX; (B) image reconstructed with AIR™ Recon DL at maximum SNR improvement. Note the clarity of the median nerve in the AIR™ Recon DL image.

Images courtesy of HSS

includes a tunable SNR improvement level expressed as mild, medium and maximum to accommodate user preference. AIR™ Recon DL includes an innovative ringing suppression technology: rather than simply removing Gibbs ringing, the network recognizes where ringing occurs and recasts this former artifact into improved image detail. The result is an image with high SNR and spatial resolution that is virtually free of truncation artifacts.

With AIR™ Recon DL, the potential is for technologists to acquire higher SNR without a time penalty and for radiologists to have more consistency and quality in the images they interpret. Alternatively, scan time may be reduced without compromising detail or SNR.

For example, if an MR technologist decreases slice thickness or in-plane pixel size, the amount of signal is proportionately reduced, which typically leads to noisier images. With AIR™ Recon DL, the result is higher SNR images and this may enable radiologists to be more confident in their reading and reporting.

The best of both worlds

Pascal Roux, a radiologist at Centre Cardiologique du Nord (CCN), one of the first global clinical sites to evaluate AIR™ Recon DL for GE, believes that AIR™ Recon DL is a solution that offers a dramatic improvement over existing image reconstruction techniques. "In my experience, AIR™ Recon DL demonstrated high-resolution images with no truncation artifact, imperceptible noise and depiction of sharp structure," Dr. Roux says. As of the end of August 2019, CCN had performed nearly 1,000 exams with a prototype version of AIR™ Recon DL.

In one case, he was able to detect a lesion on a spinal cord exam that was difficult to appreciate on the images processed without AIR™ Recon DL. In Dr. Roux's opinion, the lesion was more clearly visible on the images processed with AIR™Recon DL (Figure 2).

> "Anytime a new technology can help improve resolution, it will help us to better analyze lesions."
>
> *Dr. Pascal Roux*

Reading an AIR™ Recon DL image is very natural and comfortable for Dr. Roux. He expects to be more confident in his diagnosis because AIR™ Recon DL is designed to help improve SNR and image sharpness, which can enhance spatial resolution as well as help remove artifacts and reduce acquisition time.

"I have the best of both worlds. I do not have to choose between improving the quality of the exam and shortening the exam time," he says.

AIR™ Recon DL is an excellent tool to improve workflow. If Dr. Roux's department can increase the number of exams even by a fraction each hour, the cumulative result at the end of the day could be significant. With a three-exam-each-hour schedule, Dr. Roux believes it is possible to add five to six more patients in a 12-hour day.

The shorter acquisition time also means that when he needs to capture an additional image for a difficult case, he can do it without worrying about the schedule.

"Sometimes a sequence fails, or you get great information and want to add something," Dr. Roux explains. "It is hard to do that when an MR exam is 20-30 minutes. However, if we can go faster because we can reconstruct it with a deep-learning solution such as AIR™ Recon DL, then we have sufficient time to do this in the scan room."

Finding the "sweet spot"

The Hospital for Special Surgery (HSS) is another of several global sites evaluating AIR™ Recon DL and its impact on image

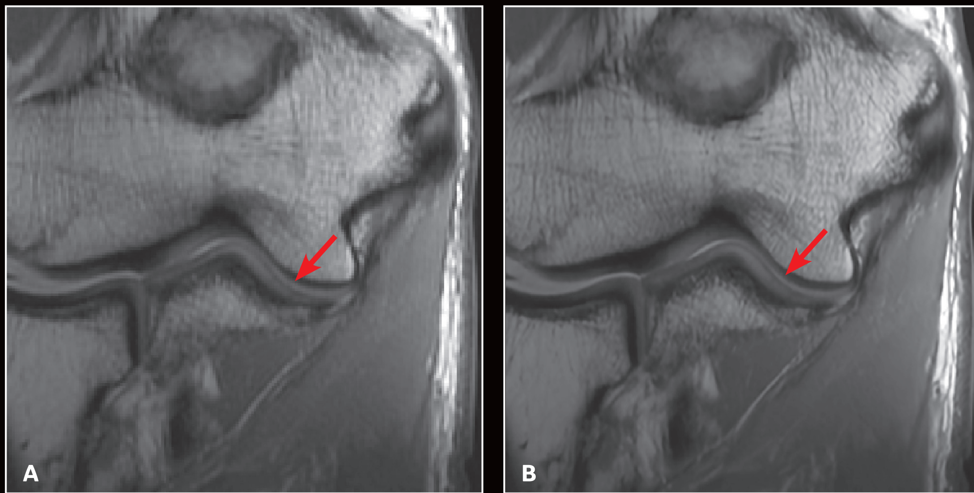


Figure 4. Coronal PD 2D FSE image of the elbow depicts normal ulnotrochlear cartilage. (A) Standard protocol, 512 x 352, 14 cm FOV, 1 NEX; (B) AIR™ Recon DL at maximum SNR improvement more clearly demonstrates the superficial cartilage layer (lamina splendens) and subchondral bone.

Images courtesy of HSS

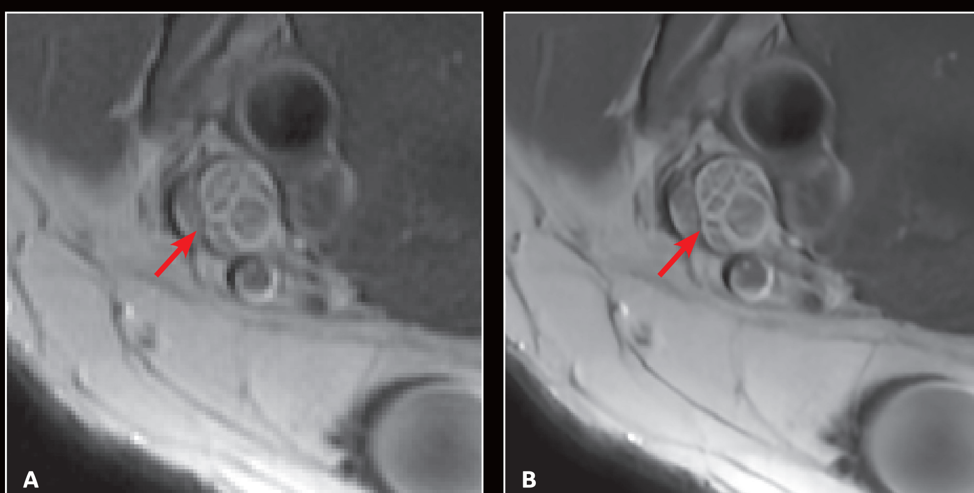


Figure 5.Axial PD 2D FSE image through the arm in a patient with a severe, spontaneous median neuropathy. (A) 512 x 352, 12 cm FOV, 2 NEX; (B) AIR™ Recon DL at maximum SNR improvement more clearly depicts fascicular detail and enlargement.

Images courtesy of HSS

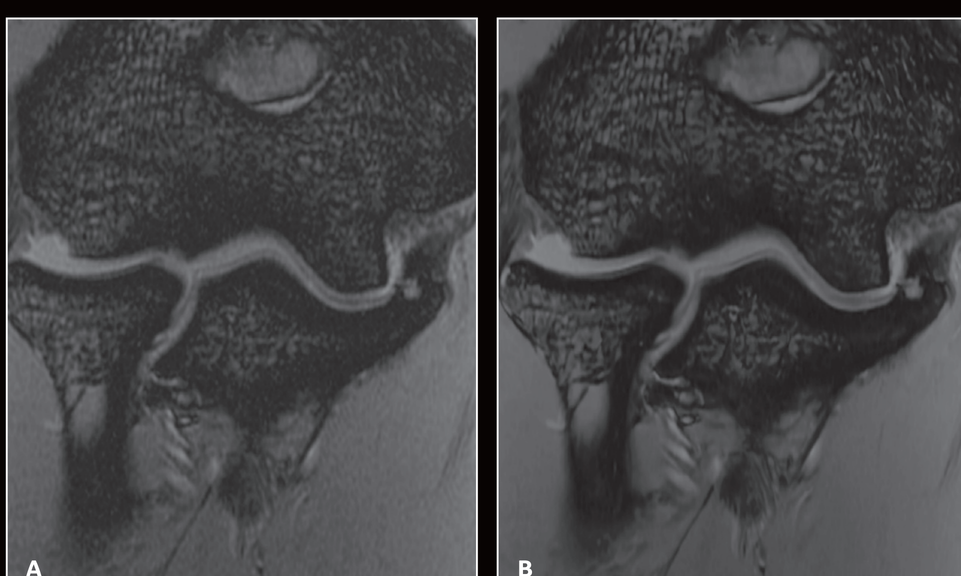


Figure 6. (A) Standard protocol. Coronal T2* GRE, 0.3 x 0.6 x 1.7 mm; (B) AIR™ Recon DL at maximum SNR improvement.

Images courtesy of HSS

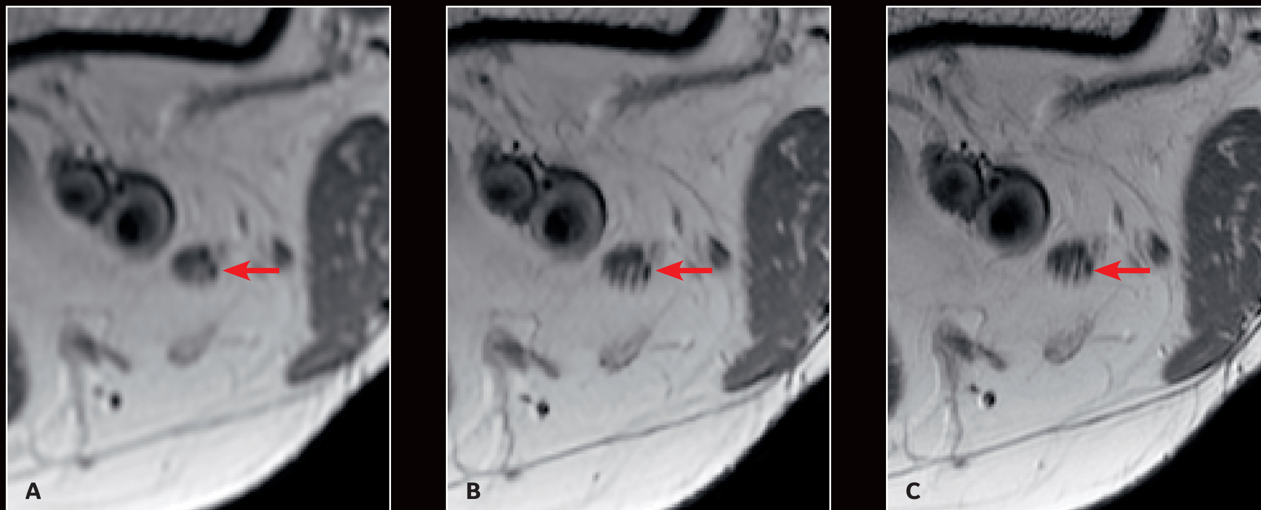


Figure 7. Elbow. (A) Unfiltered, axial 2D FSE, 256 x 180, 1 NEX, 1:10 min. (B) AIR™ Recon DL at maximum-plus SNR improvement, 256 x 180, 1 NEX, 1:10 min. (C) Reference unfiltered, 512 x 352, 2 NEX, 4:09 min.

Images courtesy of HSS

quality, spatial resolution and acquisition scan time. Darryl Sneag, MD, Director of Peripheral Nerve MRI, Erin Argentieri, senior lead research specialist and Hollis Potter, MD, Chairman, Department of Radiology and Imaging, examined the use of AIR™ Recon DL in peripheral nerve and musculoskeletal (MSK) imaging.

"AIR™ Recon DL provides the added resolution that we need when looking at musculoskeletal structures, such as ligaments, tendons, nerves and the trabecular detail of the bones," says Dr. Sneag.

The difference is like 'night and day' for Dr. Potter, particularly when using a 512 x 512 matrix with one excitation (1 NEX). With AIR™ Recon DL, trabecular detail is not blurred and the individual nerve fascicles are clearly demonstrated (Figures 3 and 4). Previously, at a 512 x 512 matrix, SNR would be a challenge, but with AIR™ Recon DL, Drs. Potter and Sneag can push the MR system to a higher matrix and achieve impressive imaging results.

> "In our experience, this tool enables us to back off on the number of averages or achieve a higher matrix, to either save on scan time or achieve a higher resolution image."
>
> *Dr. Hollis Potter*

"There is more detail in the image, especially at a lower matrix. In some conventionally-processed MR images, the trabecular pattern is poor, the nerves are blurred and there is a lot of noise in the image. With AIR™ Recon DL, the difference is striking," Dr. Potter says (Figure 7).

Dr. Potter adds that with the high-resolution AIR™ Recon DL images, she can confidently evaluate the internal architecture of the nerve — something she couldn't routinely see before.

"In my opinion, we are seeing better image quality and faster radiology reads. This will help us be more confident in our diagnosis," she adds.

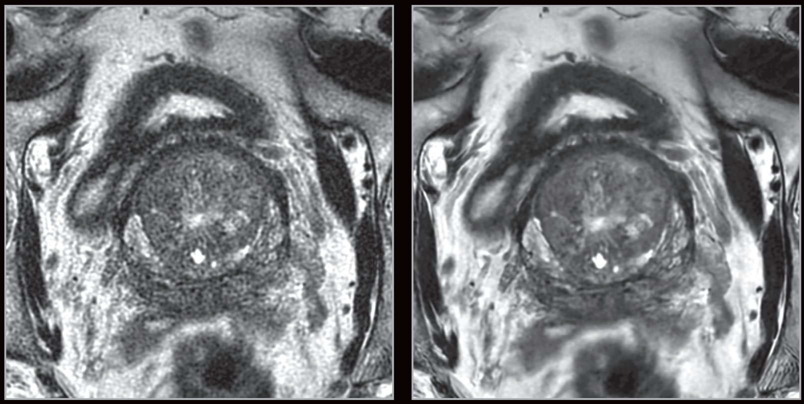
With AIR™ Recon DL, the power of deep learning and neural networks is unleashed in MR image reconstruction. AIR™ Recon DL was designed to improve SNR and image sharpness, thereby improving image quality in MR exams.

Beyond enhancing image quality, AIR™ Recon DL complements GE's AIR x™ automatic prescription and AIR Touch™ workflow tools to help improve scan consistency and usability, and potentially help facilitate shorter scan times.

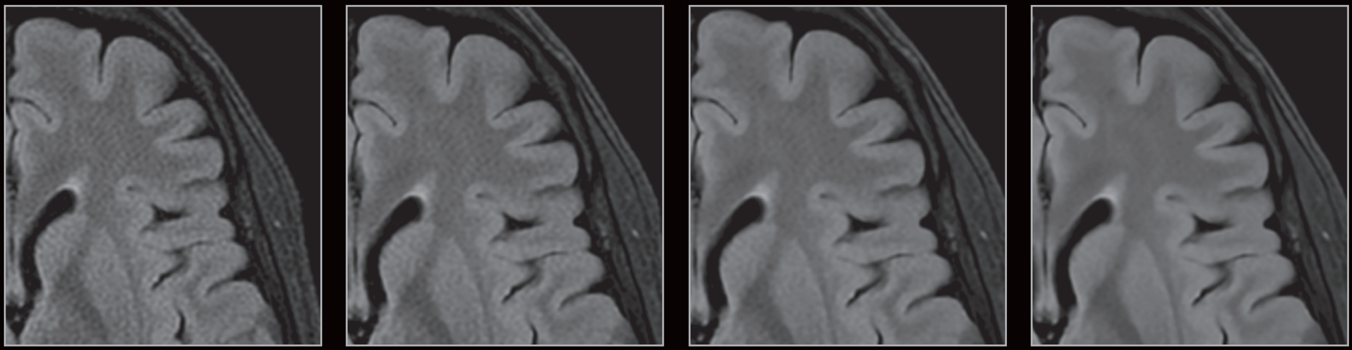
Based on initial evaluations at HSS and CCN, AIR™ Recon DL demonstrates that it can provide high-quality images across a variety of anatomies and scan protocols and has the potential to reduce scan times while preserving high image quality for more efficient exams.

Editor's note: *The editors gratefully acknowledge the assistance of R. Marc Lebel, PhD, Lead Scientist, Julie Poujol, PhD, Research Scientist and Anja C.S. Brau, PhD, General Manager, MR Collaboration & Development, in the development of this article.*

AIR™ Recon DL gallery

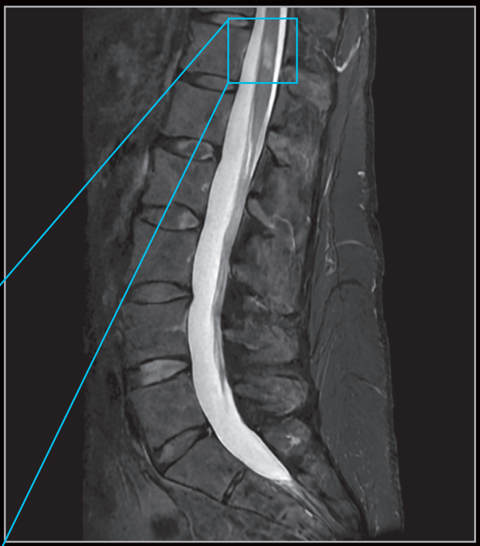


AIR™ Recon DL‡ recovers a high-quality image from an otherwise noisy thin-slice axial T2 prostate image acquired in only 1:07 min.



Original image | Mild SNR improvement | Medium SNR improvement | Maximum SNR improvement

With AIR™ Recon DL, images can be reconstructed with mild, medium or maximum SNR improvement for visibly improved image quality compared to the original image.



Sagittal STIR lumbar spine reconstructed without (left) and with (right) AIR™ Recon DL. Image quality in the spinal cord is clearly improved through reduced noise and ringing.
0.8 x 0.9 x 1.5 mm
2:47 min.

‡510(k) pending at the US FDA. Not yet CE marked. Not available for sale.

Rashid Al Umairi, MD, FRCR, FSCMR
The Royal Hospital
Muscat, Oman

A 10-minute comprehensive cardiac MR exam with flow quantification

By Rashid Al Umairi, MD, FRCR, FSCMR, cardiothoracic radiology consultant, The Royal Hospital, Muscat, Oman

Aortic valve regurgitation, also known as aortic valve insufficiency or aortic valve incompetence, is a valvopathy that describes leaking of the aortic valve during diastole that causes blood to flow in the reverse direction from the aorta and into the left ventricle. Patients with valvular conditions are referred to MR following an inconclusive Doppler ultrasound exam. While Doppler ultrasound is the current gold standard, it cannot always provide a precise answer on whether the patient should undergo surgery in cases with a poor acoustic window.

A cardiac MR (CMR) exam is comprised of various sequences that can provide a detailed assessment of the aortic valve and left ventricular function. It is a highly accurate method to determine the size of the aortic root, assess regurgitant parameters, determine ejection fraction, measure left ventricular size and detect underlying etiologies. However, acquiring quality cardiac sequences to quantify cardiac function and flow has historically been a complex and time-consuming exam to perform, requiring technologist expertise and physician supervision with little room for error when capturing constantly moving anatomy. Conventional CMR techniques like 2D phase contrast require multiple slice acquisitions that are perpendicular to the flow of the blood. For some pathologies, this would require the patient to hold their breath — in many cases greater than 20 times in an exam. Considering that patients who typically receive a CMR exam often have heart disease, it can be difficult for them to repeatedly hold their breath and, therefore, exams may suffer from sub-optimal or non-diagnostic image quality. Despite the value of CMR, these limitations continue to complicate image acquisition.

New technology could shift this paradigm. Several techniques enabling free-breathing flow acquisitions are under investigation. Real-time CMR is one approach to image acquisition during free-breathing that is analogous to echocardiography, or cardiac ultrasound. Using acceleration techniques, the data is rapidly acquired throughout the breathing cycle and then reconstructed to provide an average heartbeat. Alternatively, 3D CMR data can be acquired during free-breathing over several minutes using respiratory motion compensation, with data then reconstructed retrospectively.

To improve data acquisition in our institution, we have implemented the ViosWorks 4D Flow sequence in standard CMR exams. With this technique, the

SIGNA™ Artist

PARAMETERS		
	4D Flow	*FIESTA Cine*
TR (ms):	4.7	3.8
TE (ms):	2.14	Min Full
FOV (cm):	36	38
Slice thickness (mm):	2.2	8
Frequency:	170	200
Phase:	170	192
NEX:	4	1
Scan time (min):	7:25	0:09
Options/other (b value, no-phase wrap, etc.):	ZIP2	

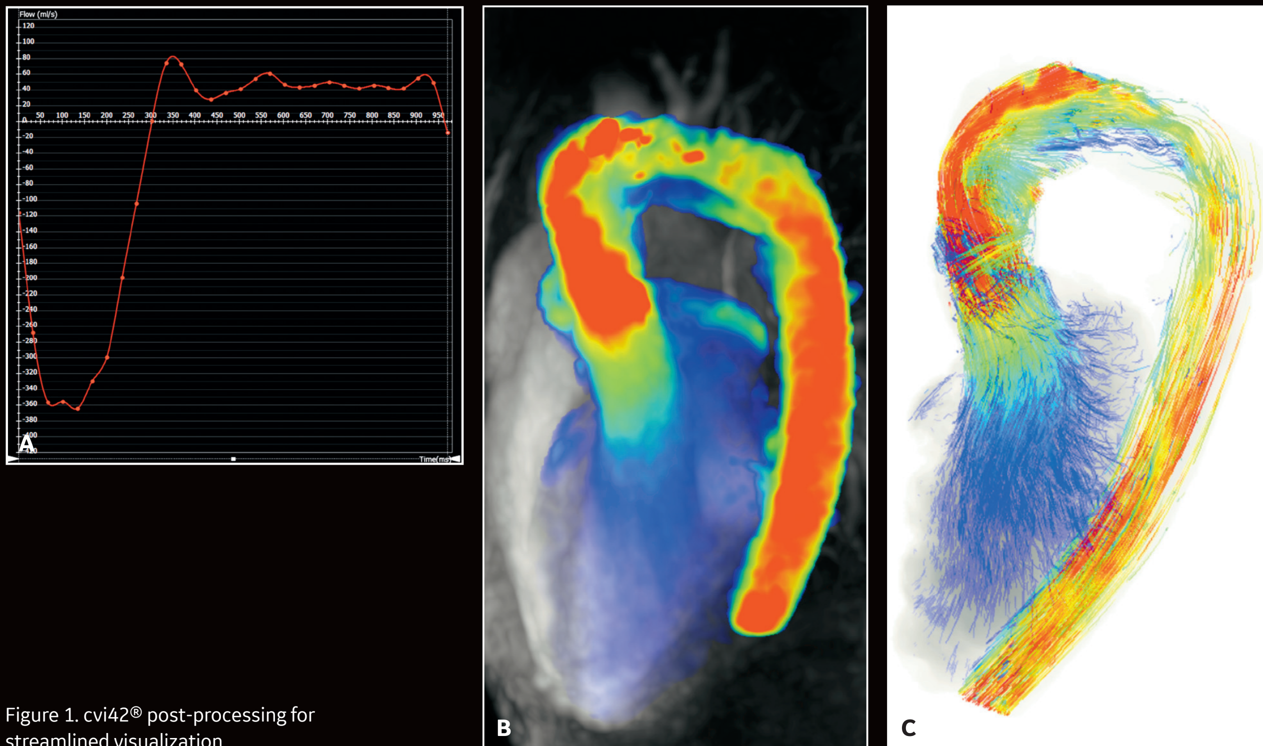


Figure 1. cvi42® post-processing for streamlined visualization.

technologist simply places the imaging volume over the patient's chest and data acquisition is completed with no breath-holds. There is little interaction necessary on the front end and immediate reconstruction of the images in order to review instantly, which is helpful to ensure the proper velocity encoding (VENC) of the vessel before the patient gets off the table. The image can be reformatted to an arbitrary plane and blood flow in the entire volume can be quantified retrospectively in offline processing.

The 4D Flow data can be used to measure blood flow velocity and direction in any part of the cardiovascular system, including flow quantification in the ascending aorta and main pulmonary artery, as well as in patients with congenital heart disease. This approach is particularly attractive because these patients frequently require flow measurements to be made in multiple vessels and at various levels within that vessel. Using traditional 2D CMR sequences, flow in each location is measured from a separate acquisition that needs to be set up precisely from separately acquired localizer images, resulting in prolonged scan times.

With ViosWorks 4D Flow, the volume of data is enough to cover the entire chest. Isotropic images are gated and timed to the breathing cycle to provide high spatial resolution with 2 mm^3 slices, enabling retrospective reformatting in any image orientation.

Patient history

A 24-year-old male with an unremarkable medical history presented with recurring shortness of breath on exertion. On auscultation, the patient was found to have a heart murmur. He was referred for further assessment with echocardiogram, which revealed severe aortic regurgitation with dilated left ventricle and systolic dysfunction. The patient underwent CMR for an accurate measurement of aortic regurgitation and to investigate the cause of left ventricle dilatation.

Technique

The ViosWorks 4D Flow sequence was performed on a 1.5T SIGNA™ Artist and was completed in as little as 10 minutes with the patient free-breathing. This technique provides quantitative cardiac measurements including flow, regurgitant fraction, stroke volume, ventricular volumes and ejection fraction.

MR findings

Patient diagnosed with bicuspid aortic valve, a congenital disorder, and vortex, or twisted, flow.

Aortic flow (obtained by analyzing 4D Flow):

- Total forward volume: 93 ml
- Backward volume: 35 ml
- Forward volume: 58 ml
- Regurgitation fracture: 38%

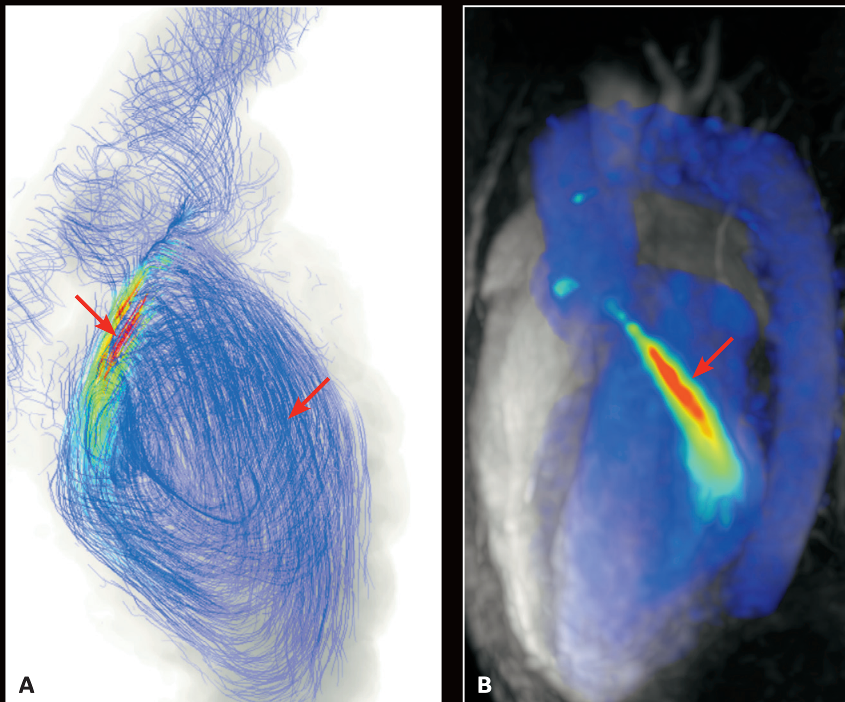


Figure 2. Using cvi42® it is possible to detect regurgitation flow (arrows).

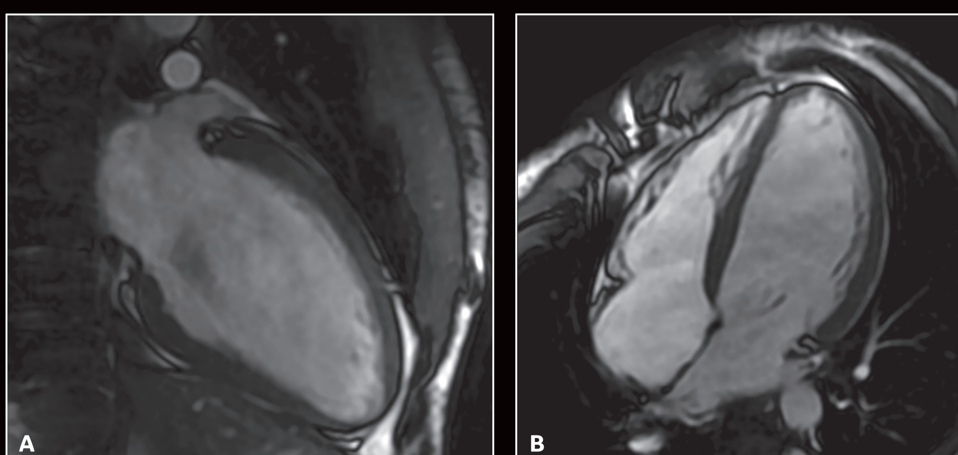


Figure 3. (A) 2-chamber FIESTA Cine and (B) 4-chamber FIESTA Cine.

Left ventricle function and volume:

- Ejection fraction: 60%
- LVEDV/BSA: 141 ml/m^2 (dilated)

ViosWorks 4D Flow provided a complete view of anatomy of the heart, including the flow within the four chambers and large vessels. This allowed us to study flow patterns throughout the cardiac cycle and to visualize turbulences and quantify flows such as regurgitations. As a result, we were able to diagnose vortex, or twisted flow, which is a blood flow that has separated from the central streamlines within a vessel and countercurrent to the main flow direction. This condition was only diagnosed by using 4D Flow and was not seen on conventional 2D phase contrast or echocardiography.

Discussion

The 4D Flow technique provides the information needed for basic flow quantification and appears promising for more advanced hemodynamic analysis, including pressure gradients, wall shear stress, pulse wave velocity and kinetic energy. It delivers high-resolution images depicting volumetric, cardiac-motion-resolved heart anatomy and blood flow with improved exam efficiency and minimal or no breath-holding, addressing many of the challenges facing CMR today. With ViosWorks, for the first time all seven dimensions of information — 3D in space, 1D in time and 3D in velocity — can be captured in a 10-minute or less free-breathing cardiac exam.

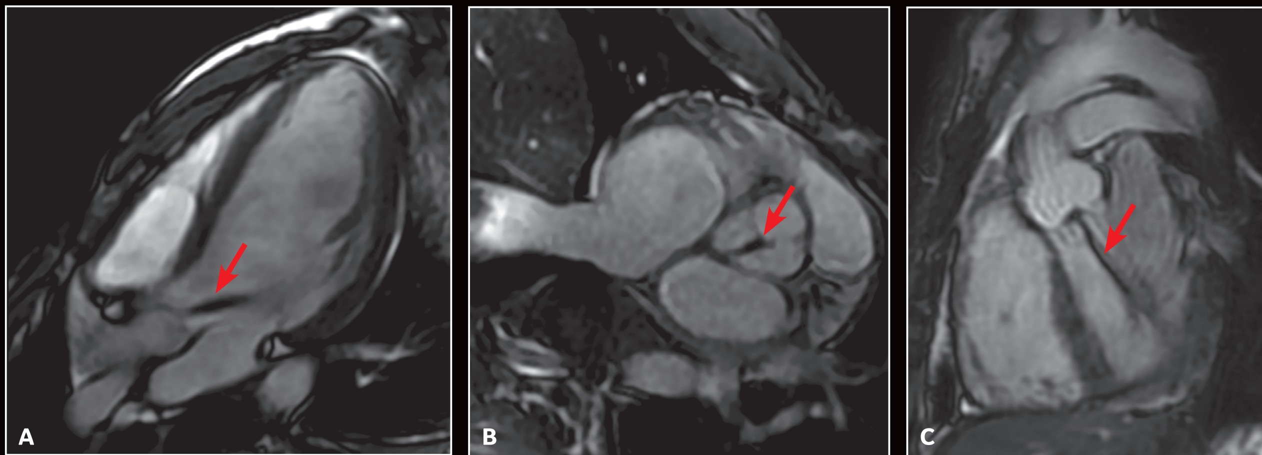


Figure 4. (A) 3-chamber LVOT FIESTA Cine for evaluating function; (B) short axis FIESTA Cine; and (C) sagittal oblique FIESTA Cine perpindicular to the aortic valve demonstrating the flow jet from regurgitation.

Figure 5. (A) 2-chamber, (B) 4-chamber and (C) short axis PS MDE, post-contrast.

ViosWorks 4D Flow has enabled us to accurately measure trans-stenotic pressure gradients non-invasively in aortic coarctation. Previously, this could only be measured invasively in the cardiac catheterization lab.[1] It may also be possible to identify alterations in hemodynamics that can affect the growth of aneurysms or development of atherosclerotic plaque.

As important, 4D Flow has simplified image acquisition and reduced overall exam time in patients with congenital and valvular heart disease. The use of an acceleration technique has played a significant role in reducing scan time by exploiting data correlations in space. Prescription of the image plane is important to obtain a true double oblique image. Otherwise it is possible for the flow data to be incorrect. Further, a key benefit of 4D Flow is that it acquires comprehensive flow data for the entire data set. We can then go back and process the data retrospectively; if a clinical question is raised after the exam, we can go back and perform additional measurements and process additional flow information from the vessel in the field of view without rescanning the patient.

We are also using the Circle cvi42® post-processing software based on deep learning for faster image analysis. What once took hours of computer processing time now can be accomplished in minutes.

Today, ViosWorks 4D Flow is preferred clinically at The Royal Hospital Muscat. 4D Flow is a technology that may change our cardiac imaging practice and we are convinced that this technique will play a more important role in the near future for evaluating patients with cardiac disease.

Reference

1. Fusman B, Faxon D, Feldman T. Hemodynamic rounds: Transvalvular pressure gradient measurement. Catheter Cardiovasc Interv. 2001 Aug;53(4):553-61.

Abdelhamid Derriche, MD
PRIISM, EHP Kara
Oran, Algeria

Orkia Ferdagha
PRIISM, EHP Kara
Oran, Algeria

Detecting ischemia-induced cardiac fibrosis with phase sensitive MDE

By Abdelhamid Derriche, MD, site radiologist, and Orkia Ferdagha, MR technologist, PRIISM, EHP Kara

In cardiac patients, particularly those who have a history of ischemia, determining myocardial viability is critical for planning the patient care pathway as it allows us to identify patients who would not benefit from angioplasty. Myocardial delayed enhancement (MDE) sequences are typically employed for these studies.

A strong saturation of healthy myocardium signal on MDE sequences allows for a better delineation and assessment of ischemic induced cardiac fibrosis. However, the most optimal inversion time value (TI) is needed for acquiring a reliable and clinically useful MDE study. Cine IR allows us to obtain this value even though the TI time continually changes as the contrast washes out.

The introduction of a phase sensitive MDE (PS MDE) sequence now allows for better suppression of healthy myocardium signal even with non-optimal TI values. Additionally, we can avoid rescanning patients in cases of poorly suppressed healthy myocardium signal due to incorrect TI value selection by only evaluating the PS MDE sequence (see Figure 1).

SIGNA™ Explorer

PARAMETERS

	FIESTA Gated Cine SA	*FIESTA Gated Cine LA*	*FIESTA Gated Cine 4 chambers*	*FIESTA Gated Cine LVOT*	*Tagging SA*	*Perfusion, multi planes in SA + 4 chambers*	*2D MDE SA*	*2D MDE 4 chambers*	*2D MDE LA*	*PS MDE SA*
TR (ms):	4.3	4.3	4.1	4.3	5	3.3	4.9	4.8	4.7	7.6
TE (ms):	1.9	1.9	1.8	1.9	2.3	1.6	1.4	1.4	1.3	3.5
FOV (cm):	38	38	38	38	40 x 28	38 x 34.2	40 x 36	40 x 36	40 x 36	38 x 34.2
Slice thickness (mm):	8	8	8	8	8	10	9	9	9	9
Frequency:	224	224	224	224	256	128	224	224	224	200
Phase:	224	224	224	224	192	96	160	160	160	192
NEX:	1	1	1	1	1	0.75	3	3	3	1
Scan time (min):	1:15	1:17	1:09	0:19 (sec.)	1:49	1:04	2:06	1:59	2:11	2:00
Options / other:							After 8 min. of contrast bolus			After 25 min. of contrast bolus

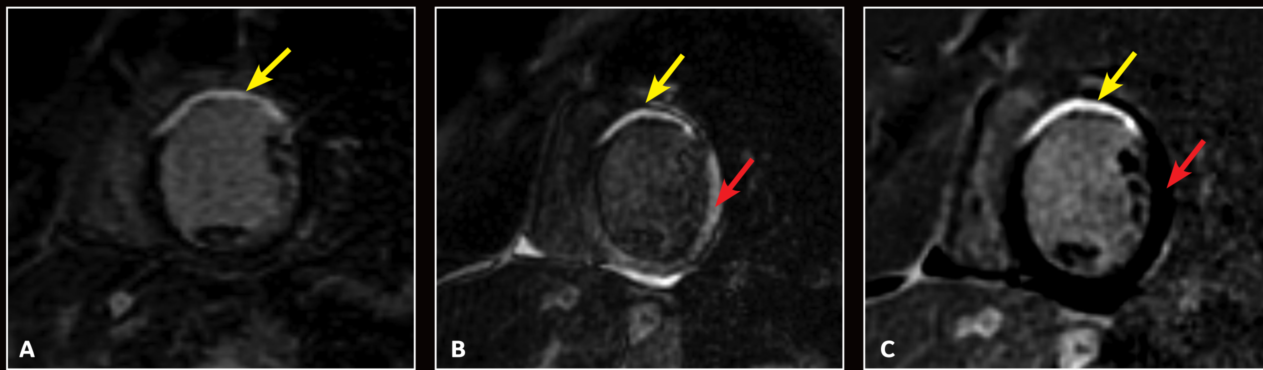


Figure 1. Comparison of 2D MDE and PS MDE. PS MDE provides better visualization of the fibrosis and better suppression of healthy myocardium signal even with non-optimal TI values. (A) 2D MDE SA, 2:06 min; (B) magnitude PS MDE; (C) phase PS MDE SA. Yellow arrows indicate ischemia induced fibrosis; (B-C) red arrows depict a healthy myocardium signal not suppressed on magnitude PS MDE with sub-optimal TI value; using the phase sensitive image from the same acquisition helped to fix this issue.

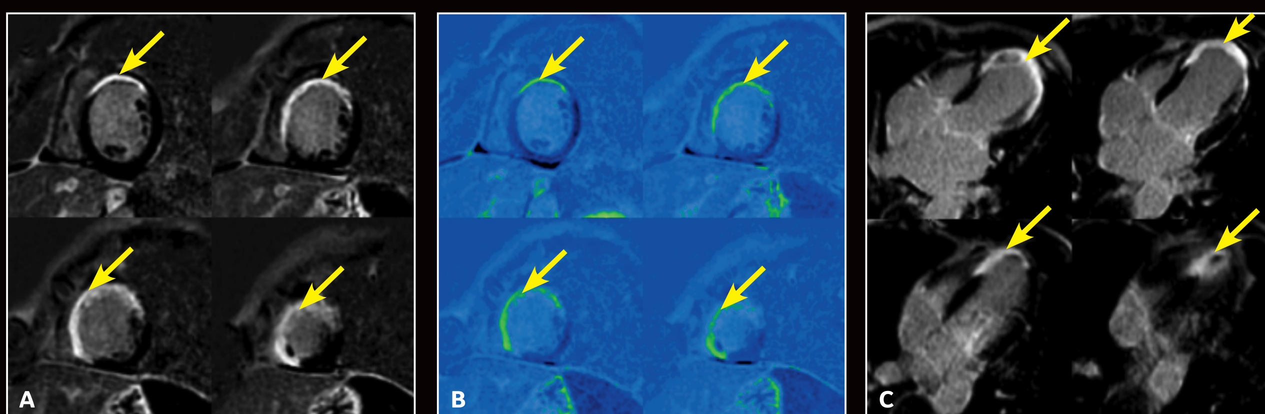


Figure 2. Myocardial viability study. (A, B with color map) 2D PS MDE SA, 1:59 min.; and (C) 2D MDE 4 chambers, 2 min. Yellow arrows indicate ischemia-induced fibrosis.

Patient history

A 60-year-old male with a history of cardiac ischemia referred for a myocardial viability MR exam including function, perfusion and the qualitative analysis of the myocardial viability. The patient has ischemia-induced fibrosis on diseased heart tissues.

MR findings

The left ventricular (LV) function study provides an estimated fractional ejection of 24% and depicts a diffuse akinetic apical contraction with midventricular hypokinesia with anteroseptal predominance.

Perfusion study shows an anomaly with delayed and reduced contrast enhancement with predominance on the subendocardial antero-septo-lateral midventricular region.

MDE demonstrates a systematic myocardial fibrosis belonging to the left anterior descending (LAD) coronary territory (see Figure 2). With contrast uptake we found:

- Transmural on apical anteroseptal;
- Transmural on midventricular septal;
- Inferior to 50% of myocardial thickness on subendocardial anterior midventricular region;
- Sub-endocardial no-reflow phenomenon on the infero-septal region of the apex (also observed on perfusion sequence);
- No regional myocardial parietal thinning of less than 6 mm.

Patient underwent angioplasty and recovered some cardiac function.

Discussion

Using PS MDE, it was possible to assess myocardial necrosis with systematized transmural fibrosis on the LAD coronary territory in the apical anteroseptal region and midventricular septal region as non-viability criteria. Additionally, we determined myocardial ischemia

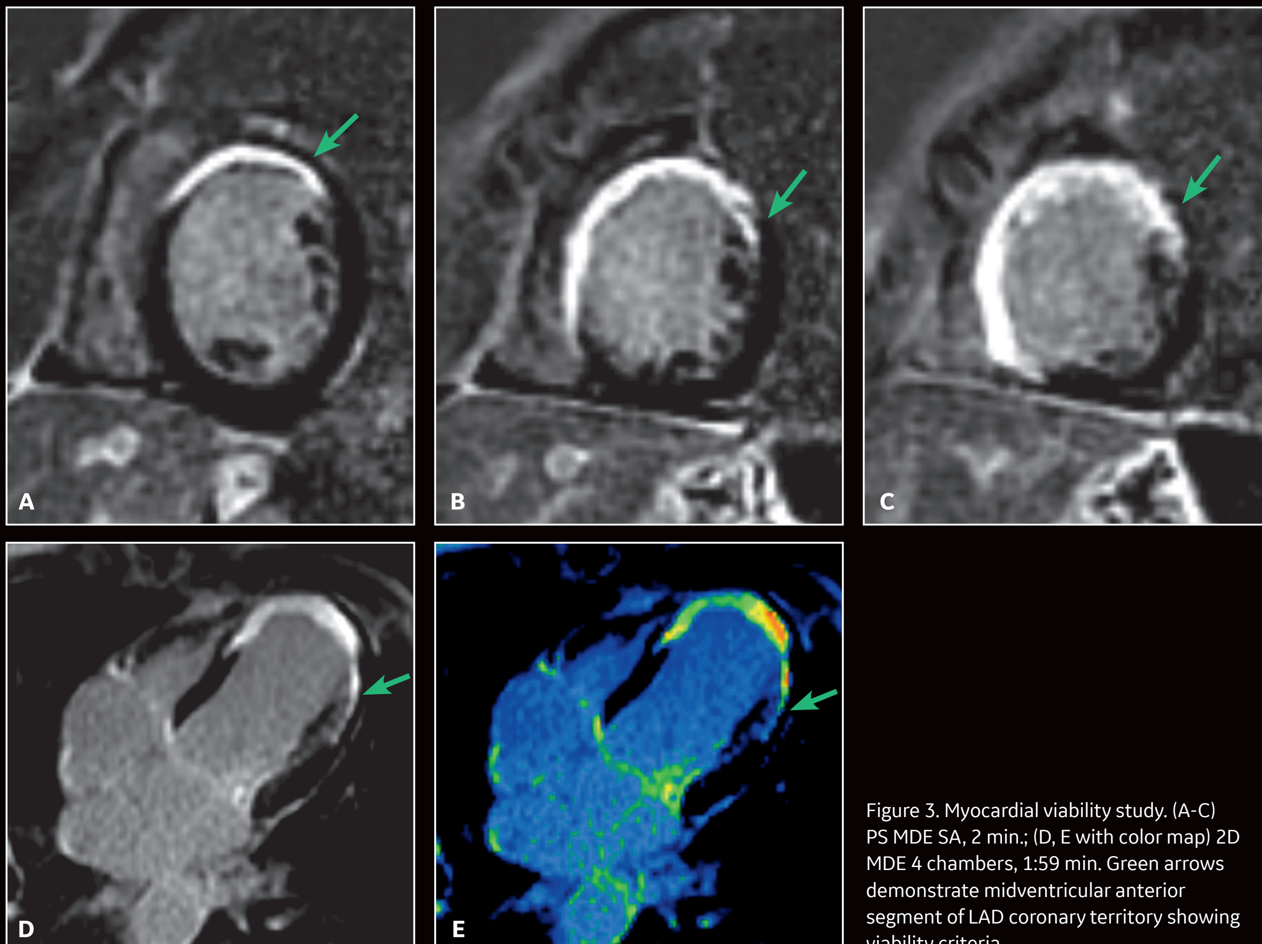


Figure 3. Myocardial viability study. (A-C) PS MDE SA, 2 min.; (D, E with color map) 2D MDE 4 chambers, 1:59 min. Green arrows demonstrate midventricular anterior segment of LAD coronary territory showing viability criteria.

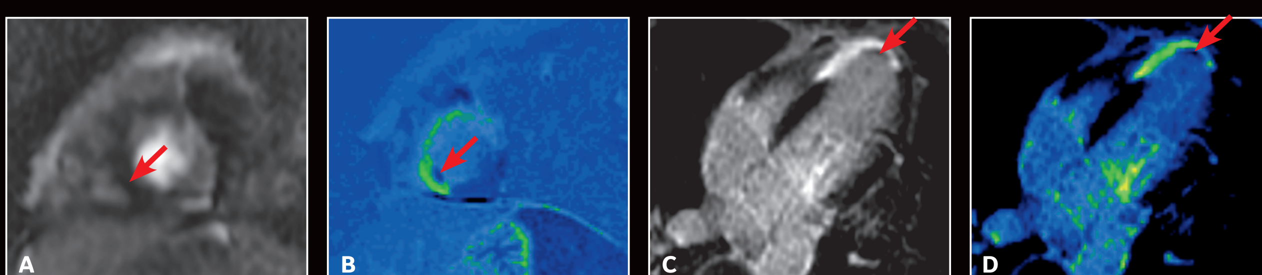


Figure 4. (A) Perfusion FGRE TC SA, 1:04 min.; (B) PS MDE SA with color map, 2 min.; and (C, D with color map) 2D MDE 4 chambers, 1:59 min. Red arrows show the sub-endocardial no-reflow phenomenon on the inferoseptal region of the apex.

with subendocardial fibrosis inferior to 50% of parietal thickness of the anterior segment of the midventricular region with viability criteria as well as hypokinesia of apical and midventricular regions with diminution of LV fractional ejection.

Cardiac MR (CMR) brings a new level of detail and depth to our diagnosis and management of coronary disease. In particular, it supports management of hypertrophic cardiomyopathy patients and post-operative follow-up in Tetralogy of Fallot cases. With CMR and an advanced 1.5T MR system such as SIGNA™ Explorer, we have higher clinical confidence due to excellent imaging capabilities that assists us in myocardium viability studies as well as diagnosing difficult-to-detect conditions, such as myocarditis and arrhythmogenic right ventricular dysplasia. CMR on the SIGNA™ Explorer adds real value to patient care.

Vicente Martinez de Vega, MD

University Hospital Quiron Salud,
Madrid, Spain

Diagnosing focal myocardial hypertrophy in a 15-minute cardiac MR exam using ViosWorks

By Vicente Martinez de Vega, MD, Head of Diagnostic Imaging Service, University Hospital Quiron Salud Madrid, Spain

Optima™ MR450w GEM

PARAMETERS		
	4D Flow	*3D 2 Slabs*
TR:	4.1 ms	4.4 ms
TE:	2.1 ms	2.1 ms
FOV:	42 cm	40 cm
Bandwidth:	62.5	125
Slice thickness:	2.4 mm	8 mm
Frequency:	172	200
Phase:	172	200
Flip angle:	14	65
ARC acceleration:	Phase x 1 Slice x 1	Phase x 1 Slice x 1
Velocity encoding:	250-350	
Hyperkat:	x 8	x 8
NEX:	4	1
Overlap loc:		0
Locs per slab:		10

Introduction

A comprehensive cardiac MR (CMR) study routinely requires inclusion of cardiac volume measurements and global/segment cardiac function. However, this type of patient exam can be very lengthy to acquire the necessary information—often 60 to 90 minutes requiring 20 to more than 50 breath-holds. In some cases, this can also lead to suboptimal imaging results as many patients undergoing CMR may be acutely ill and unable to remain still and hold their breath throughout the study.

Typically, a CMR exam will include 2D FIESTA sequences in short axis to determine left ventricular function and remodeling fraction and stroke volume; information on the blood flow acceleration in the left ventricular outflow tract using 2D phase-contrast sequences; and delayed, or late, enhancement to detect the presence of fibrosis as well as characterize a wide range of ischemic and non-ischemic cardiomyopathies.

One aspect of a CMR exam that consumes the most time is obtaining white blood images to assess morphology and function using 2D FIESTA sequences acquired in short axis. Replacing this scan with a short axis 3D acquisition acquired in one or two breath-holds is very important as it can save a significant amount of time. For example, scan time of a typical 2D Cine acquisition is 8-10 minutes. In this particular patient case presented below, the 3D Cine scan time was 39 seconds to acquire two slabs, representing a scan time reduction of approximately 92%.

Post-processing of CMR imaging data is another time-intensive process. However, by using the cloud-based, deep learning segmentation of ViosWorks, powered by Arterys™, we can significantly shorten the time needed to review and correct the segmentation. Typically, viewing and correction time of 3D Cine using ViosWorks is less than one minute. In the case presented, the total time spent viewing and correcting the automatic segmentation was 2:15 min due to the complexity of the hypertrophy cardiomyopathy requiring a greater degree of manual correction.

Figure 1. ViosWorks can significantly shorten the time needed to review and correct the segmentation in CMR exams.

Acquisition and processing time

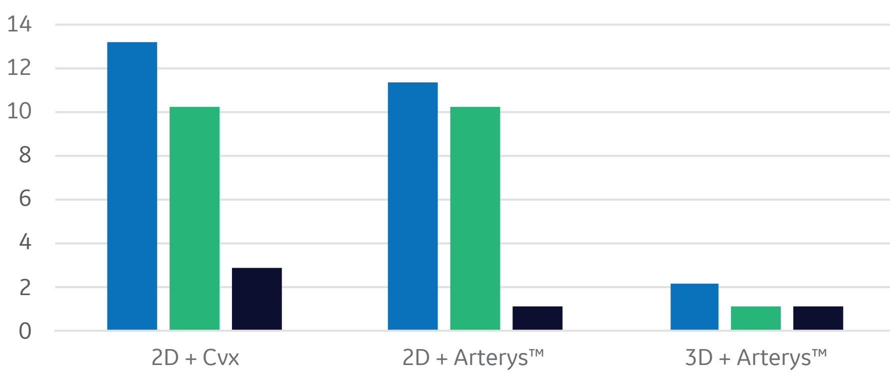


Figure 2. A comparison of (1) 2D Cine scan time + time needed to review and correct ViosWorks segmentation with (2) 3D Cine acquisition time + time needed to review and correct ViosWorks segmentation. 3D Cine with deep learning segmentation leads to shorter examination and analysis time.

Patient history

A 35-year-old patient presented with a complaint of palpitations. ECG indicated arrhythmias and a prior echocardiography exam demonstrated a focal hypertrophic cardiomyopathy affecting the anteroseptal basal region with left ventricular outflow tract obstruction. Anterior displacement of the mitral apparatus and systolic anterior motion (SAM) of the mitral anterior leaflet was also noted.

A CMR exam was indicated for the evaluation of myocardial hypertrophy and areas of fibrosis (using late enhancement).

Protocols used

A fast CMR exam was performed in less than 15 minutes with ViosWorks. The exam included:

- Real-time planning
- 3D Cine short axis
- 4D Flow after intravenous
- contrast injection
- Late enhancement (single shot)

MR findings

The 3D Cine short axis sequence, in a scan time of 39 seconds, provided a left ventricular ejection fraction of 75% and a left ventricular stroke volume of 74.75 ml/beat.

With an acquisition time of 6:30 minutes, the 4D Flow sequence provided a gradient pressure of 29 mmHg with eccentric jet flow in the tubular ascending aorta with turbulent flow. Diameter of the aorta was measured at 31 mm.

The single-shot late enhancement sequence consisted of a short axis acquired in 34 seconds and a long axis acquired in 34 seconds. An intramural enhancement was detected inside the hypertrophic myocardium consistent with the presence of fibrosis.

Total CMR scan/acquisition time: 7:37 minutes.

Ventricular function analysis, scan time and processing time: 2:10 minutes.

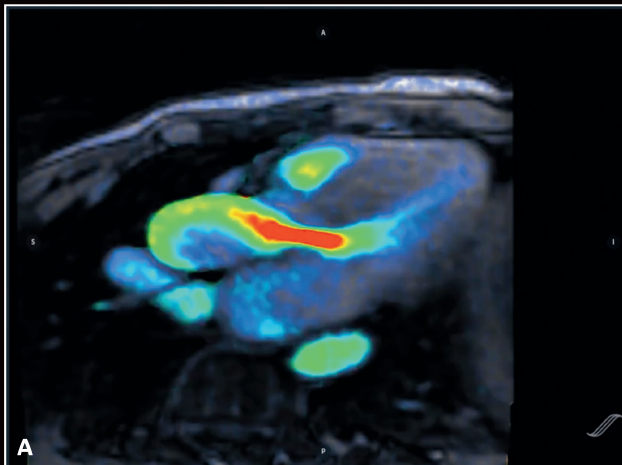
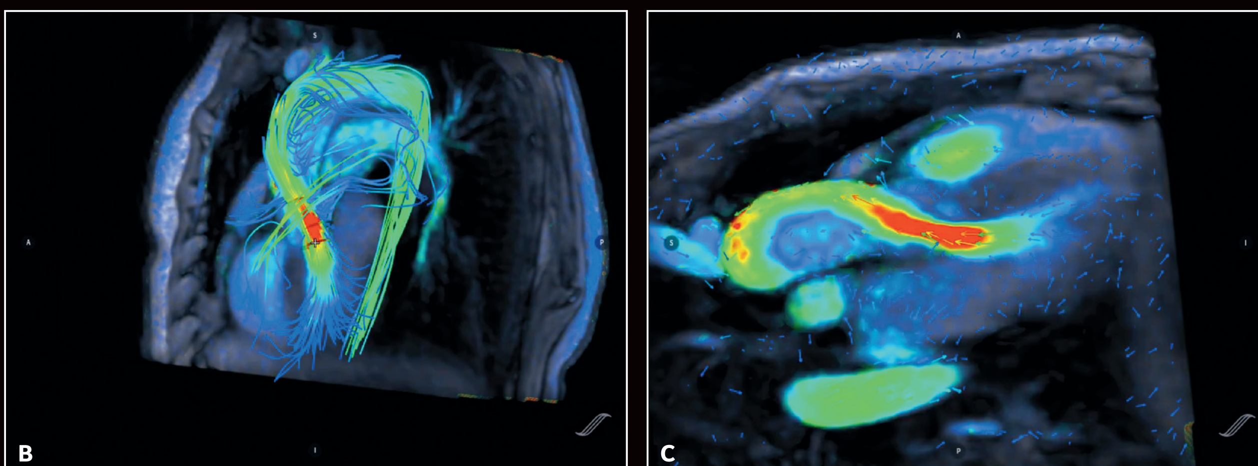


Figure 3. (A) Flow acceleration in the left ventricular outflow tract due to myocardial hypertrophy. (B, C) Eccentric jet flow in the tubular ascending aorta with turbulent flow. Diameter of the aorta: 31 mm.



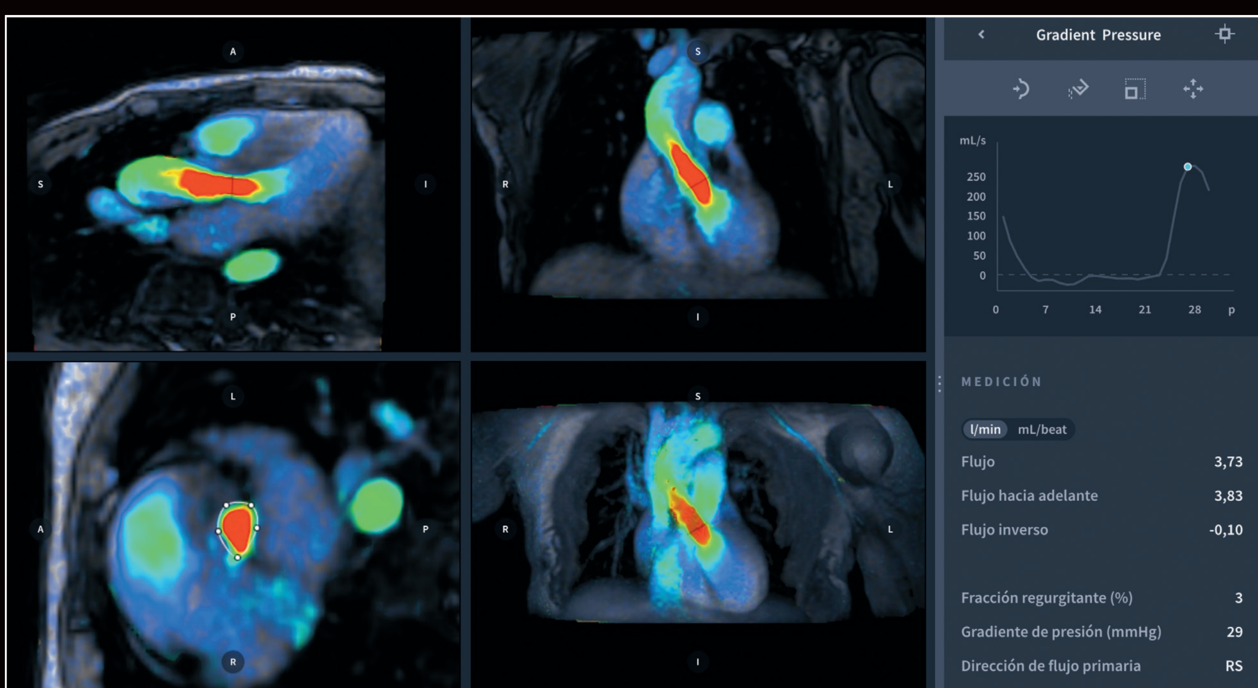


Figure 4. Gradient Pressure: 29 mmHg.

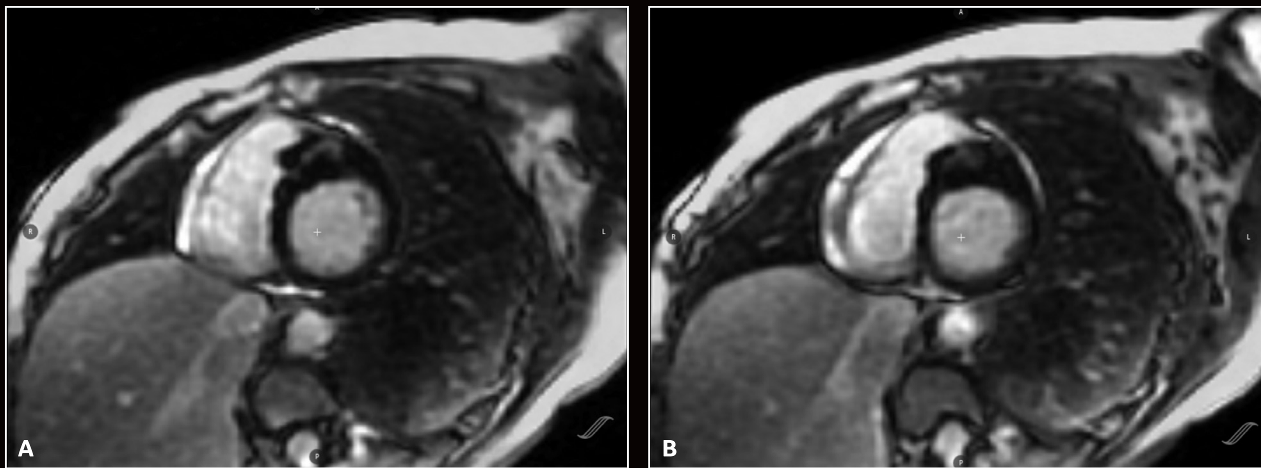


Figure 5. Short axis. Late enhancement (single shot).

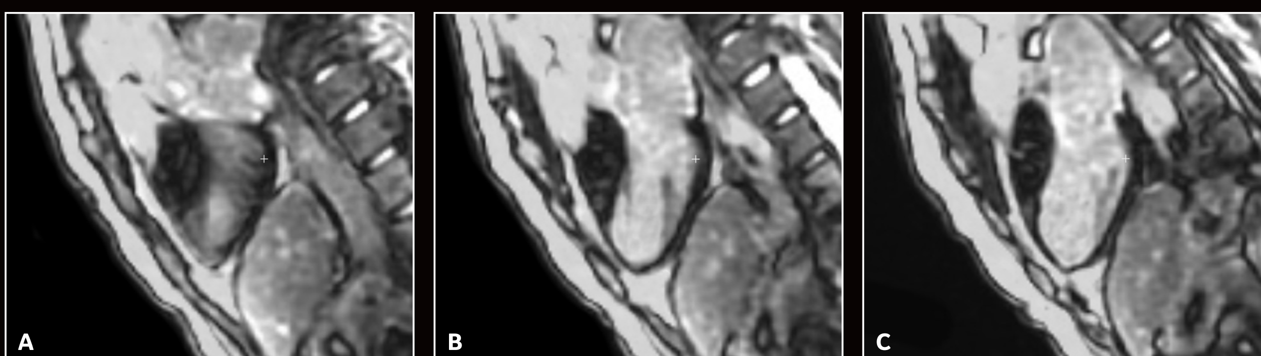


Figure 6. Long axis. Late enhancement (single shot).

Discussion

The main drawback of CMR is the long acquisition and interpretation times. Thus, a main objective is to reduce scanning and post-processing time to enhance the diagnostic quality of CMR and increase clinical productivity. Newer, fast sequences such as 3D Cine and late enhancement single shot significantly reduce scan time.

4D Flow provides comprehensive information on a patient's vascular and valvular flow with a reasonable acquisition time. This sequence has several advantages with respect to the 2D phased-contrast sequences:

- Flow volume measurements with 4D Flow have good internal consistency
- QP/QS is obtained in the same dataset (same cardiac cycle)
- Retrospective placement of analysis planes at any location
- Valve tracking may improve assessment of flow in the heart valves
- Free breathing
- Easy to prescribe

The post-processing capabilities of ViosWorks using deep learning algorithms delivers quantitative data and structured reporting capabilities and also reduces time and increases a radiologist's productivity. S

Stay Connected

GE Healthcare is pleased to announce that four abstracts on AIR™ Recon DL‡ have been accepted for presentations at the 2019 Annual Meeting of the Radiological Society of North America (RSNA).

Session: Physics (MRI – New Techniques and Image Quality)

SSA22-06

Improvement of Late Gadolinium Enhancement Image Quality Using a Novel, Deep Learning Based, Reconstruction Algorithm and its Influence on Myocardial Scar Quantification

Van der Velde N, Bakker B, Hassing C, Wielopolski PA, Lebel RM, Janich MA, Budde RP, Hirsch A

Erasmus Medical Center, Rotterdam, Netherlands

Session: Neuroradiology/Head and Neck (Artificial Intelligence)

SSQ15-08

Denoising MR Images of the Cervical Spine: Multi-Reader Assessment of a Deep Learning Approach

Villaneueva-Meyer J, Shin D, Li Y, Leon III PA, Banerjee S, Brau AC, Lebel RM, Glastonbury CM

University of California San Francisco

Session: Neuroradiology Monday Poster Discussions

R370-SD-MOA1

Deep-Learning Reconstruction Improves Quality of Clinical Brain and Spine MR Imaging

Bash SC, Thomas M, Fung M, Lebel RM, Tanenbaum LN

RadNet, Inc., Baltimore, MD

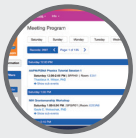
Session: Musculoskeletal (Machine Learning and Artificial Intelligence)

SSG08-08

Performance of a Deep Learning-Based MR Reconstruction Algorithm for the Evaluation of Peripheral Nerves

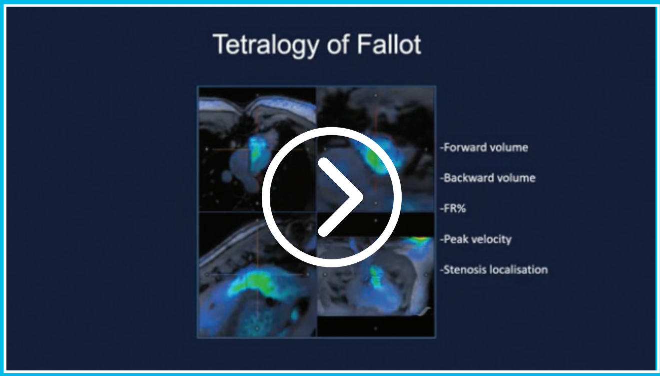
Argentieri EC, Zochowski KC, Potter HG, Shin J, Lebel RM, Sneag DB

Hospital for Special Surgery, New York, NY



To read the full abstracts online, visit: meeting.rsna.org/program/

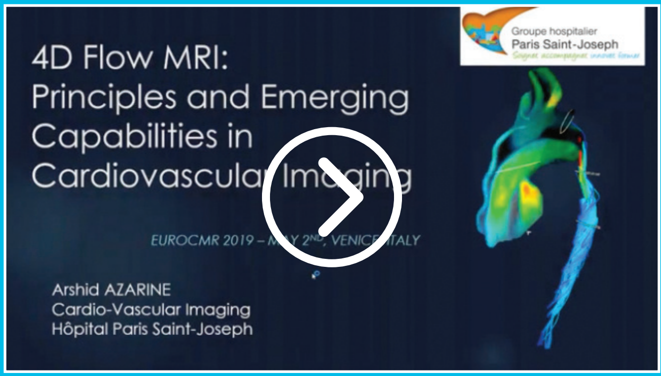
‡510(k) pending at the US FDA. Not yet CE marked. Not available for sale.



4D Flow MRI: A revolution for Congenital Heart Disease

Francesca Raimoni, MD
Hôpital Necker-Enfants Malade, Paris, France

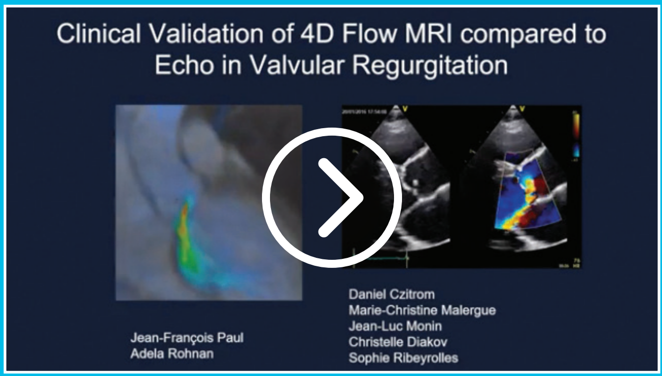
https://tinyurl.com/vmmkwpm



4D Flow: Technical principles and emerging capabilities in CMR analysis

Arshid Azarine, MD
Hôpital Paris Saint-Joseph, Paris, France

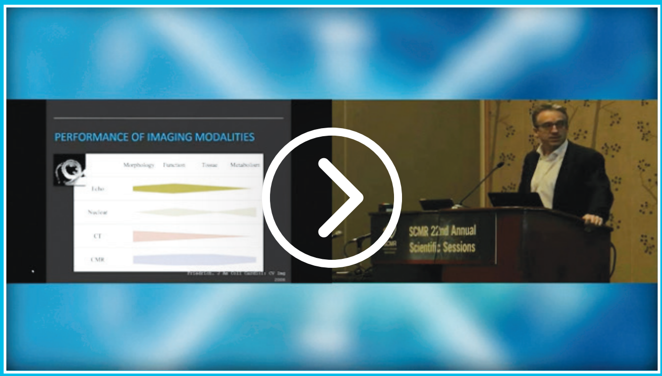
https://tinyurl.com/szr784z



Clinical validation of 4D Flow MRI for Cardiac Valvular Disease

Jean-Francois Paul, MD
Institut Mutualiste Montsouris (IMM) Paris, France

https://tinyurl.com/rv8jwvq



Short cardiac MR protocols: Where it works

Matthias Friedrich, MD
McGill University, Montreal, Canada

https://tinyurl.com/vx2qf9r

Getting consistent and quantifiable results in cardiac imaging

Alexander Hirsch, MD, PhD
Erasmus Medical Center, Rotterdam, NE

https://tinyurl.com/vxpeweq

JB74970XX