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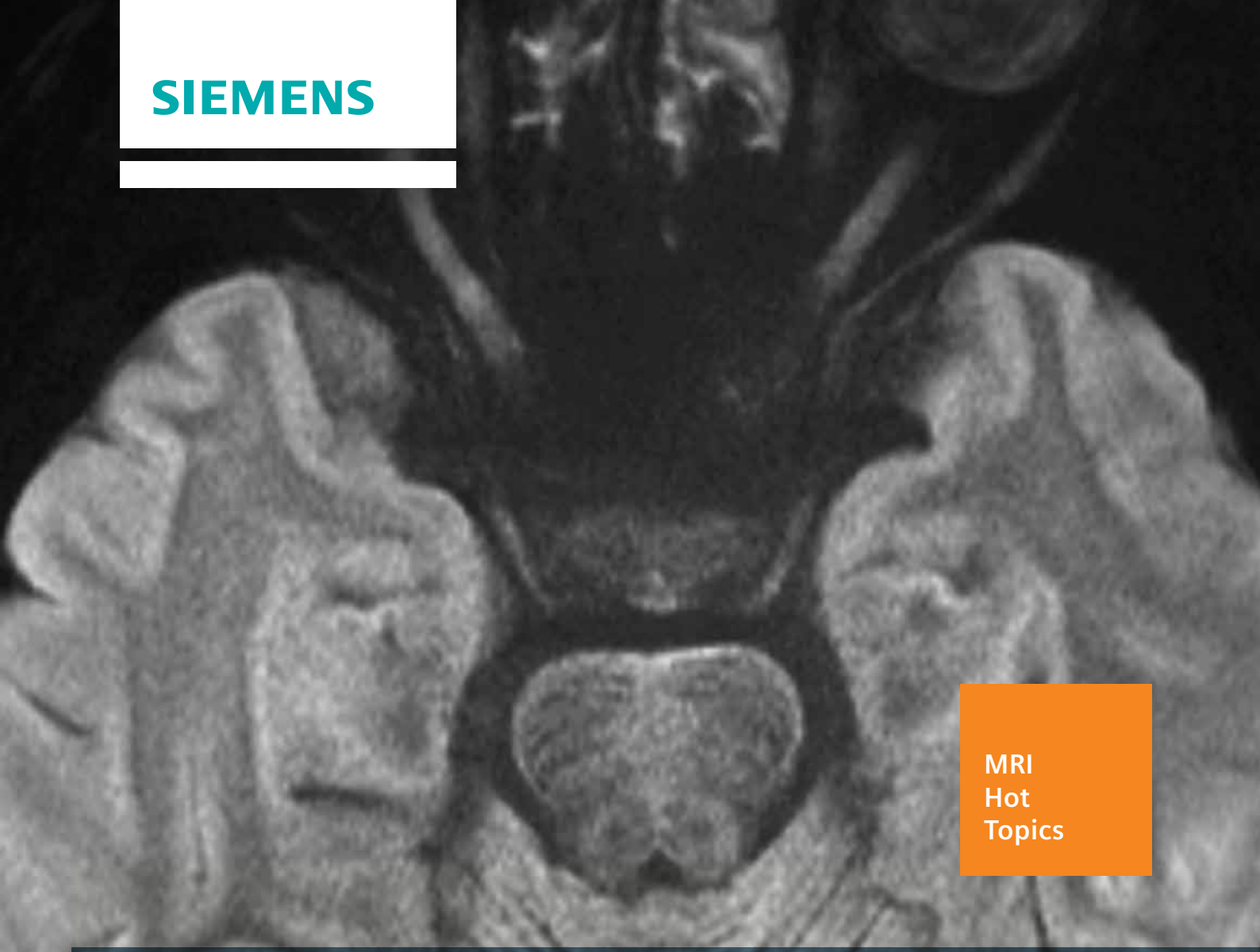

MRI
Hot
Topics

The capabilities of RESOLVE, a new diffusion MRI technique.

How to achieve higher resolution diffusion MRI to support better clinical confidence and expanded capabilities.

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Answers for life.

How to achieve higher resolution diffusion MRI to support better clinical confidence and expanded capabilities.

The capabilities of RESOLVE, a new diffusion MRI technique.

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Effective, informative, and accurate diagnostic imaging is critical for high-quality and fiscally responsible patient care. Diagnoses that are missed, wrong, or delayed affect an estimated 10 to 20 percent of cases with an enormous toll on patient management and healthcare cost.[1] For many assessments, radiologists frequently include diffusion weighted imaging (DWI) to gain a microstructural understanding of disease and treatment response. DWI can offer important clinical information that can significantly impact the speed and accuracy of diagnosis, which ultimately supports reductions in repeat imaging, faster treatment decisions, and shorter lengths of stay.

DWI is, for example, frequently used for the diagnosis of acute ischemic stroke[2-4]. Similarly, tumor assessment and lesion characterization with DWI have several advantages over other techniques. DWI eliminates the need of contrast agents as needed in X-ray myelography, contrast-enhanced CT and MRI, as well as the invasive procedures in biopsy[5-8]. Patients also benefit from DWI of the body, although this imaging is far more challenging than the brain. In conjunction with conventional morphological MR images, DWI has been recognized as a noninvasive, whole-organ-coverage tool with excellent soft tissue contrast to diagnose and stage prostate cancer[9]. The applications of DWI were also demonstrated with success in other organs or body parts, such as rectum, breast, and female pelvis[10-12].

Further, MRI is an appealing modality in pediatric† imaging, since it avoids radiation dosage and provides excellent soft tissue contrast. DWI of the brain is used in diagnosis, staging, and follow-up of children with central nervous system tumors[13]. And DWI of the spine can reveal spinal diseases that may not be visible on conventional MR images in children[14,15].

However, some anatomies and patient populations are difficult to image with DWI, so a compromise is made regarding the clinical care decision. Two characteristics of standard DWI challenge its utility for some applications: low spatial resolution and distortion. This is a problem for diagnostic quality and can hamper the applicability of diffusion MRI, especially in certain body regions such as the spine and pelvis. In addition, it poses challenges in pediatric† imaging, because the small size of the field of interest requires high spatial resolution.

†MR scanning has not been established as safe for imaging fetuses and infants less than two years of age.
The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

A new diffusion MRI technique, REadout Segmentation Of Long Variable Echo-trains (RESOLVE), is designed to overcome these limitations and significantly improve the image quality of diffusion MRI[16]. As is demonstrated in this article, RESOLVE reduces susceptibility sensitivity to better detect and delineate lesions for diagnosis and follow-up in strokes and tumors; helps in the differential diagnoses of tumors; and enables better therapy planning and dose calculation[17-23]. It provides high-resolution, low-distortion DWI, which is especially essential for diagnostic imaging of children†[14,15]. In addition, it enables high-resolution diffusion tensor imaging for difficult regions such as the spine and even small nerves (e.g., optic nerves). All these advantages have the potential to further enhance the role of DWI in existing applications and will enable diagnostic possibilities with DWI/DTI in new clinical applications that were challenging or even unfeasible. As a result, healthcare delivery organizations can expand their MRI services to better support their population health and increase referrals. And, technology that supports faster, more accurate diagnoses can lead to more cost-effective and efficient treatments that improves patient satisfaction.

Method

Distortion and low resolution can challenge conspicuity with conventional DWI due to the single-shot EPI sampling scheme where the whole k-space is acquired in a single readout in the zig-zag pattern (Figure 1A, k-space). Because the single readout needs to sample the whole k-space, the effect of susceptibility and T2* decay during this long period is pronounced and causes image blurring and artifacts (Figure 1A, conventional DWI).

RESOLVE overcomes these challenges for supreme robustness in diffusion imaging. Image quality is improved due to two major changes in the pulse sequence. First, improved sharpness, reduced artifacts, and increased SNR are achieved through the multi-shot EPI echo trains with segmentation in the readout direction (Figure 1B, k-space). The readout time of each shot is only part of the single-shot readout time, and subsequently TE and the diffusion encoding time are shortened. This reduces the effect of susceptibility and T2* decay, and therefore leads to improved image sharpness and reduced artifacts. In addition, RESOLVE can be further combined with parallel imaging by under-sampling k-space in the ky direction during imaging. This provides a further reduction in susceptibility and T2* decay artifacts by shortening the EPI echo-train length and decreasing the effective echo-spacing.

The second change that comes with RESOLVE brings precision and accuracy for uncooperative patients and hard-to-image areas that are afflicted with motion. RESOLVE incorporates a two-dimensional (2D) navigator echo (Figure 1B, Navigator)[16]. This navigator is generated by sampling the central kx segment followed by the imaging echo train at each shot, serving two purposes similar to a Global Positioning System (GPS). First, the 2D navigator data is useful in the image reconstruction to help remove the shot-to-shot nonlinear phase variation in the imaging echo data. This is analogous to the scenario where a GPS plans an optimal route for a trip and acquires the location information during the trip to follow the pre-determined route. Second, during the measurement, the 2D navigator data is used to identify the imaging scan that will result in unusable data and trigger a reacquisition process to repeat this current scan. This is equivalent to the recalculation feature of a GPS to correct and readjust the navigation route if the current location deviates from the originally planned route.

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With the combined power of readout-segmented EPI, parallel imaging techniques, and the 2D navigator, RESOLVE can provide a robust method for DWI and DTI in many applications, offering high spatial resolution and minimal image distortion (Figure 1B, RESOLVE). The DW images obtained with RESOLVE show substantially improved spatial resolution for better visualization of the anatomical detail, and significantly less distortion in challenging areas with strong susceptibilities, such as brainstem and cranial nerves (yellow arrows).

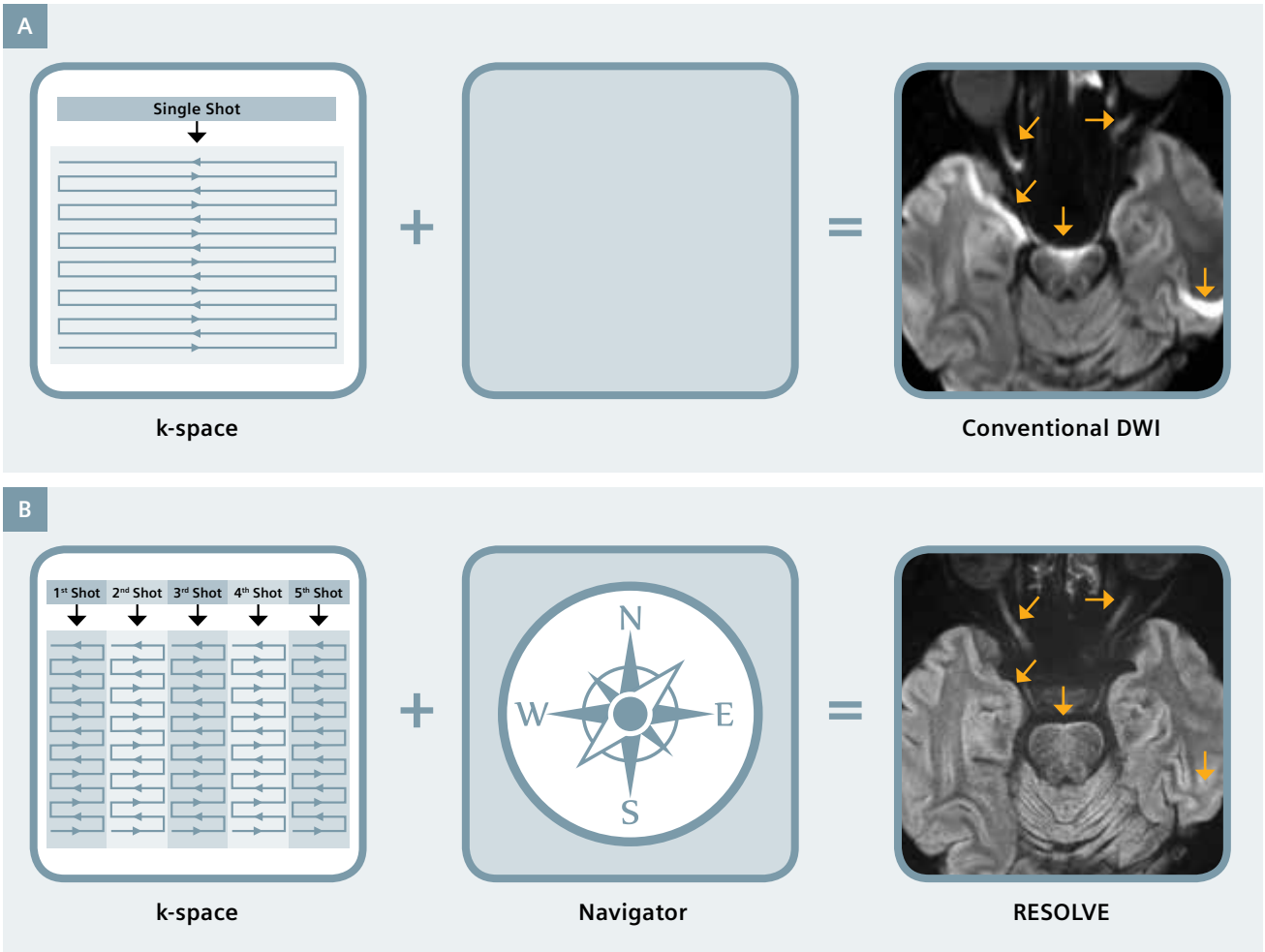

Figure 1 The data acquisition strategies and the resulting DW images of the conventional single-shot EPI (A) and RESOLVE (B). The single-shot EPI performs a single readout to sample the whole k-space. In contrast, RESOLVE performs a readout-segmented EPI trajectory to sample the k-space with the assistance of a navigator. Clinical images courtesy of Dr. Shinji Naganawa, Nagoya University School of Medicine, Japan.

Robust Solution of DWI/DTI using RESOLVE

64-year-old, brain lesion

(A): T2 weighted TSE image. (B), (C): The b1000 DW image and the ADC map of conventional single-shot EPI DWI, respectively (20 slices, 5 mm slice thickness, 130 matrix, 220-mm FOV, GRAPPA 2). (D) SWI minimum intensity projection. (E), (F): The b1000 DW image and the ADC map of RESOLVE DWI, respectively (20 slices, 5 mm slice thickness, 164 matrix, 220-mm FOV, GRAPPA 2). RESOLVE DWI provides higher anatomical correlation and less geometry distortion for better lesion delineation compared to the conventional single-shot EPI DWI.

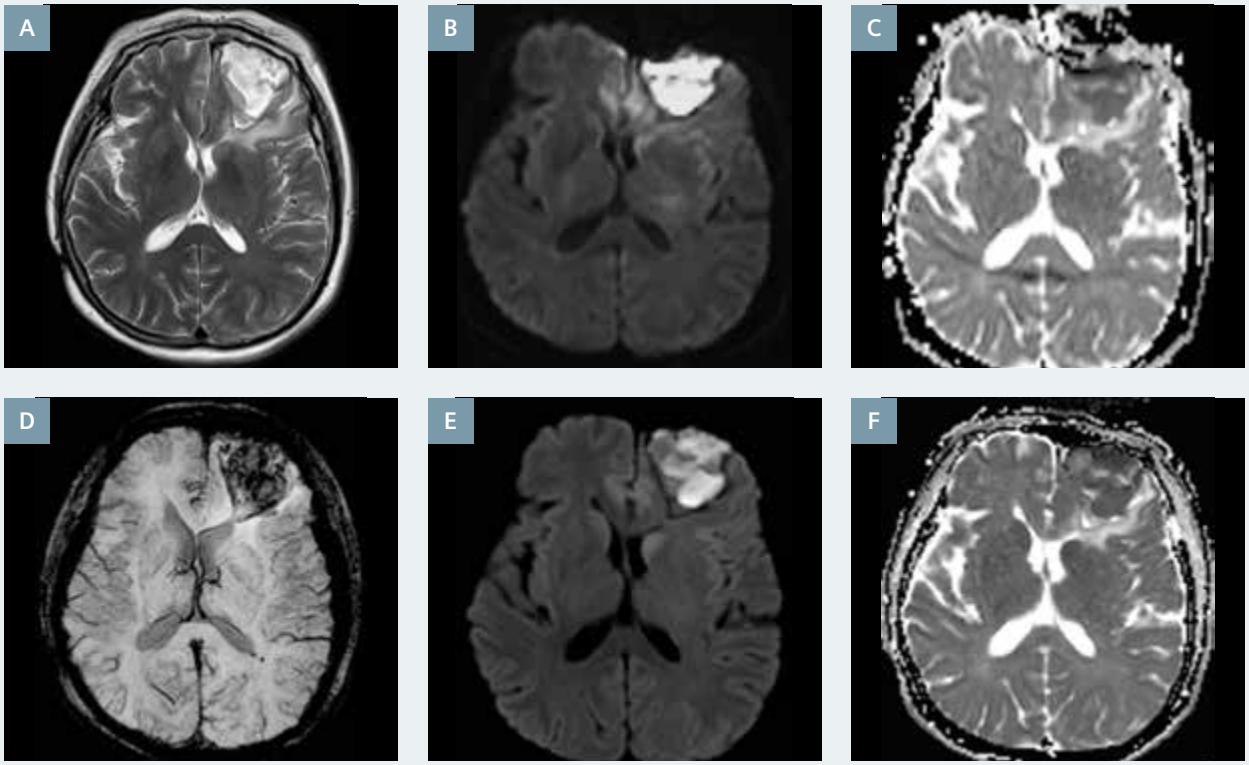

Figure 2 MAGNETOM Skyra
Clinical images courtesy of Tongji Hospital, Wuhan, China.

12-year-old, medulloblastoma with metastases

(A)-(C): Three slices of conventional single-shot EPI DWI with image blurring (b1000, GRAPPA 2, 160 matrix). (D)-(F): The same slices of RESOLVE DWI (b1000, GRAPPA 2, 224 matrix), RESOLVE DWI results in sharper images with improved spatial resolution and significantly increased image detail.

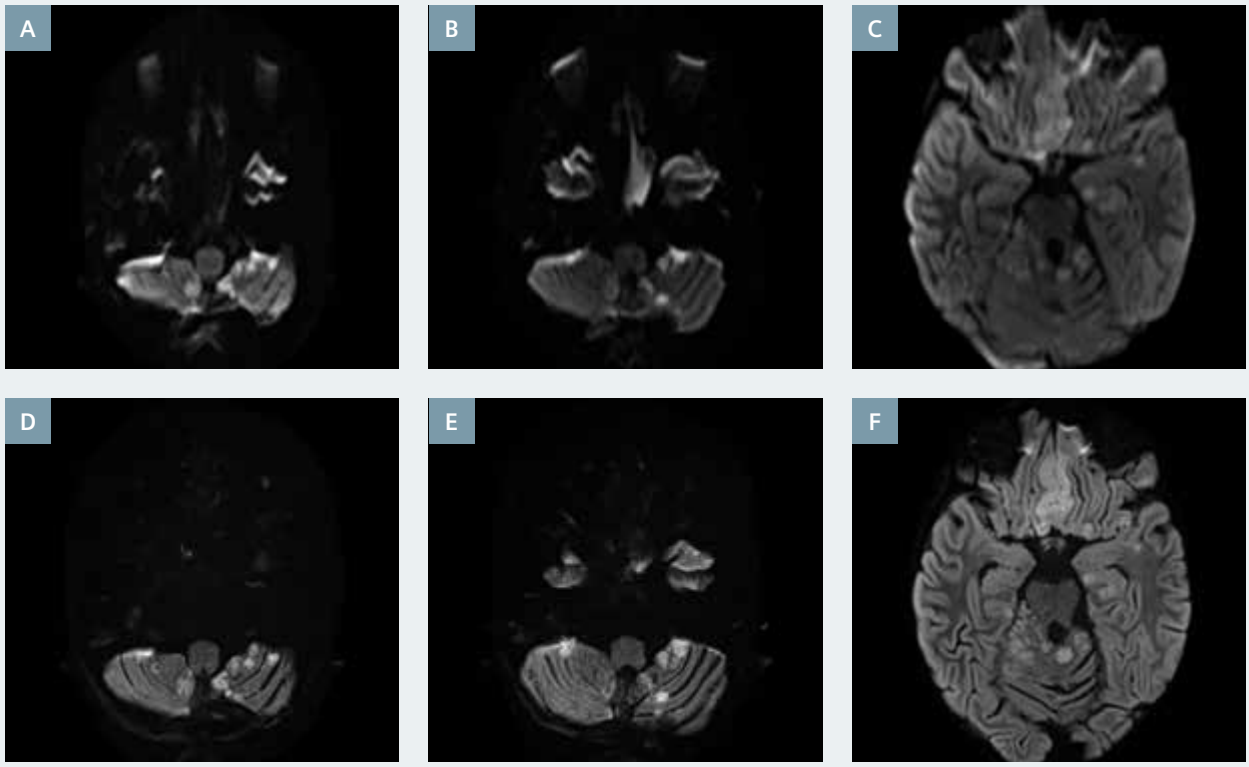

Figure 3 MAGNETOM Verio
Clinical images courtesy of Children's MRI Centre & RCH, Victoria, Australia.

Pediatric† patient, post accident (TH6 and TH12 fracture)

(A): T2 weighted TSE image. (B), (D), (F): The b650 DW image, ADC map and T1 weighted TSE fused with b0 image of the conventional single-shot EPI DWI, respectively (GRAPPA 2, 128 matrix, TA 0.05 s/slice). (C), (E), (G): The b650 DW image, ADC map and T1 weighted TSE fused with b0 image of RESOLVE DWI (GRAPPA 2, 150 matrix, TA 0.02 s/slice). Compared to the conventional single-shot EPI DWI, RESOLVE b650 DW image is free of the susceptibility artifacts (yellow arrows). The ADC map and the T1 TSE fused with b0 image also provide high anatomical correlation referring to the T2 weighted TSE image.

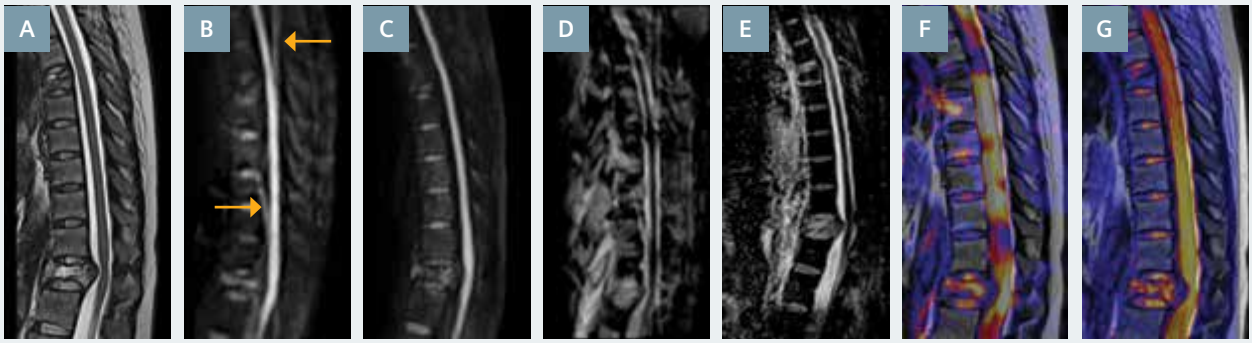

Figure 4 MAGNETOM Avanto
Clinical images courtesy of Singapore General Hospital, Singapore.

2-year-old, drop metastases to the spine

(A): T2 weighted TSE image, 2 steps composed. (B), (C), (D): The DW image with b = 5, b = 500, and ADC map of RESOLVE DWI (GRAPPA 2, 192 matrix, TA 0.08 s/slice/step). RESOLVE has reduced the susceptibility artifacts and improved spatial resolution, allowing for identification of hypercellular drop metastases in this patient, which was not visible on the corresponding T1 post-contrast images (T1 image is not pictured here, please refer to Hayes et al. 2012).[14,15]

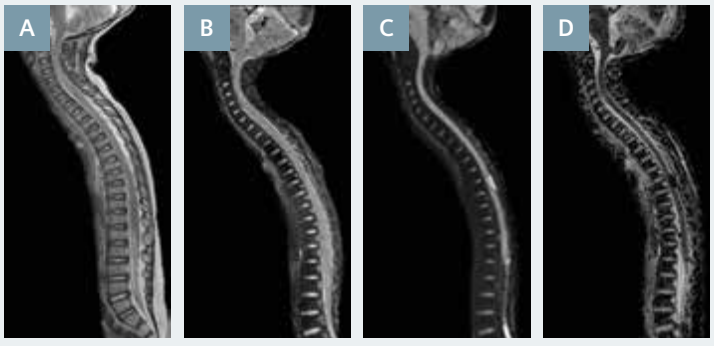

Figure 5 MAGNETOM Trio, a Tim system
Clinical images courtesy of Dr. Laura Hayes, Children's Healthcare of Atlanta at Scottish Rite, Atlanta, USA.

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Modic type I degeneration manifest as a “claw sign”

(A): The T1 weighted TSE image. (B): The T2 weighted TSE image. (C): STIR. (D), (E): The DW images of b0 and b1000 of RESOLVE DWI, respectively. The conspicuity achieved with RESOLVE in the spine allows for clear identification of the “claw sign” (yellow arrows), a recent technique for confirming the presence of true degenerative endplate changes and reducing concern for possible vertebral diskitis/osteomyelitis.[24]

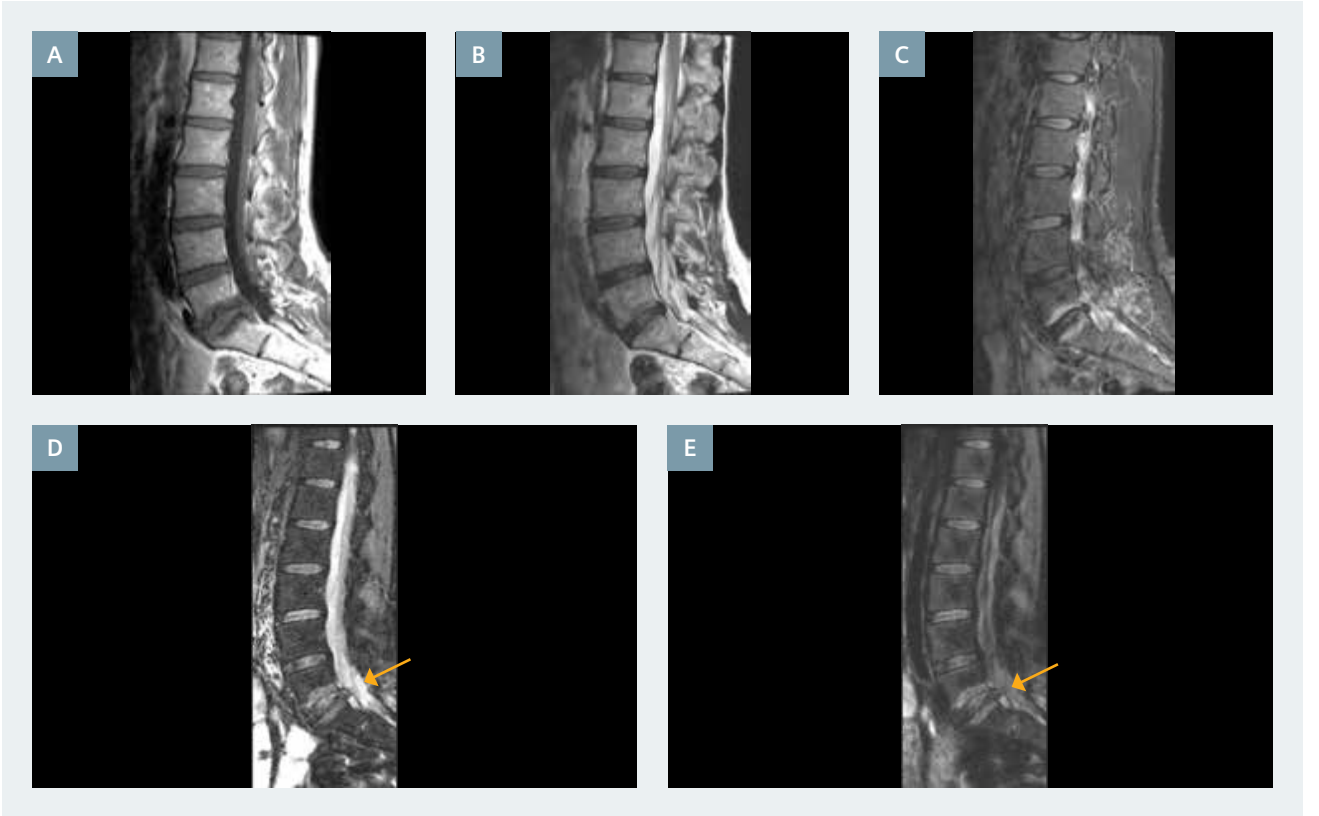

Figure 6 MAGNETOM Skyra
Clinical images courtesy of Dr. Lawrence Tanenbaum, Mount Sinai School of Medicine, New York, USA.

Prostate carcinoma

(A): The T1 weighted TSE image. (B)-(D): The DW images of b0, b1000, and ADC map of the conventional single-shot EPI DWI, respectively (GRAPPA 2, 160 matrix, TA 0.04 s/slice). (E): The T2 weighted TSE image. (F)-(H): The DW images with b0, b1000, and ADC map of RESOLVE DWI, respectively (GRAPPA 2, 192 matrix, TA 0.03 s/slice). RESOLVE DWI exhibits significantly higher spatial resolution and more detailed anatomical information for carcinoma evaluation.

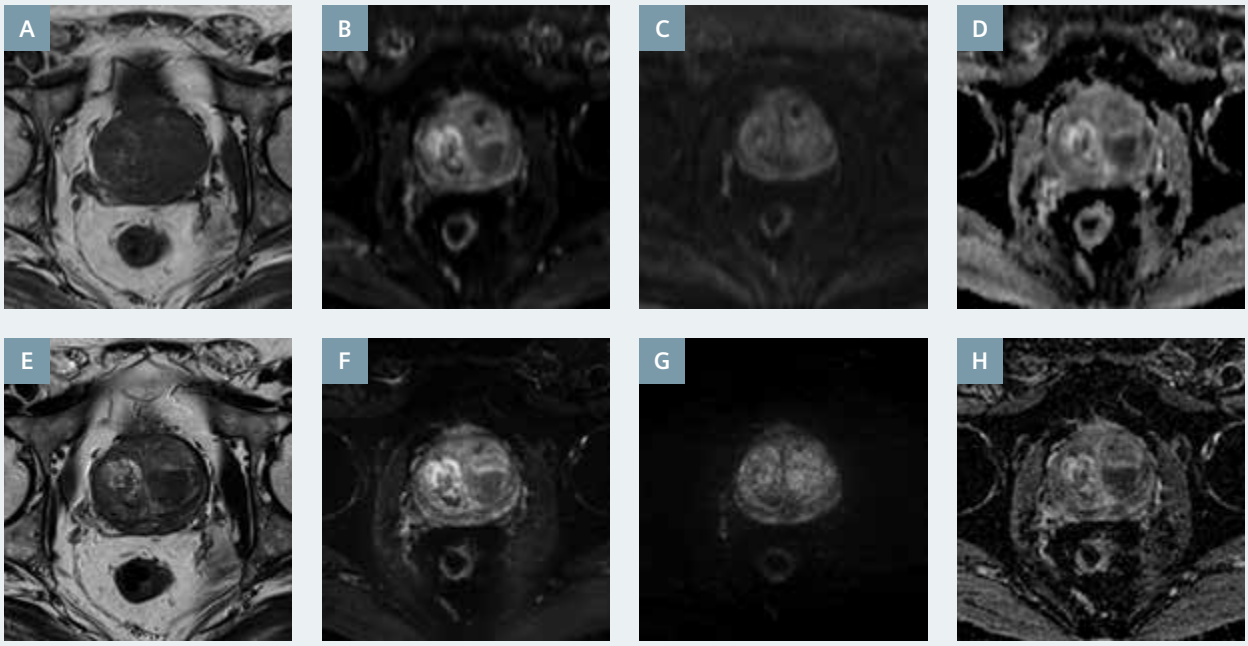

Figure 7 MAGNETOM Skyra
Clinical images courtesy of National University Hospital, Singapore.

Rectal carcinoma

(A)-(C): The DW images of b0, b1000, and ADC map of the conventional single-shot EPI DWI, respectively (GRAPPA 2, 192 matrix, TA 0.03 s/slice). (D)-(F): The DW images with b0, b1000, and ADC map of RESOLVE DWI, respectively (GRAPPA 2, 192 matrix, TA 0.03 s/slice). Compared to the conventional single-shot EPI, RESOLVE DWI exhibits higher spatial resolution and better carcinoma delineation, especially in the ADC map (yellow arrows).

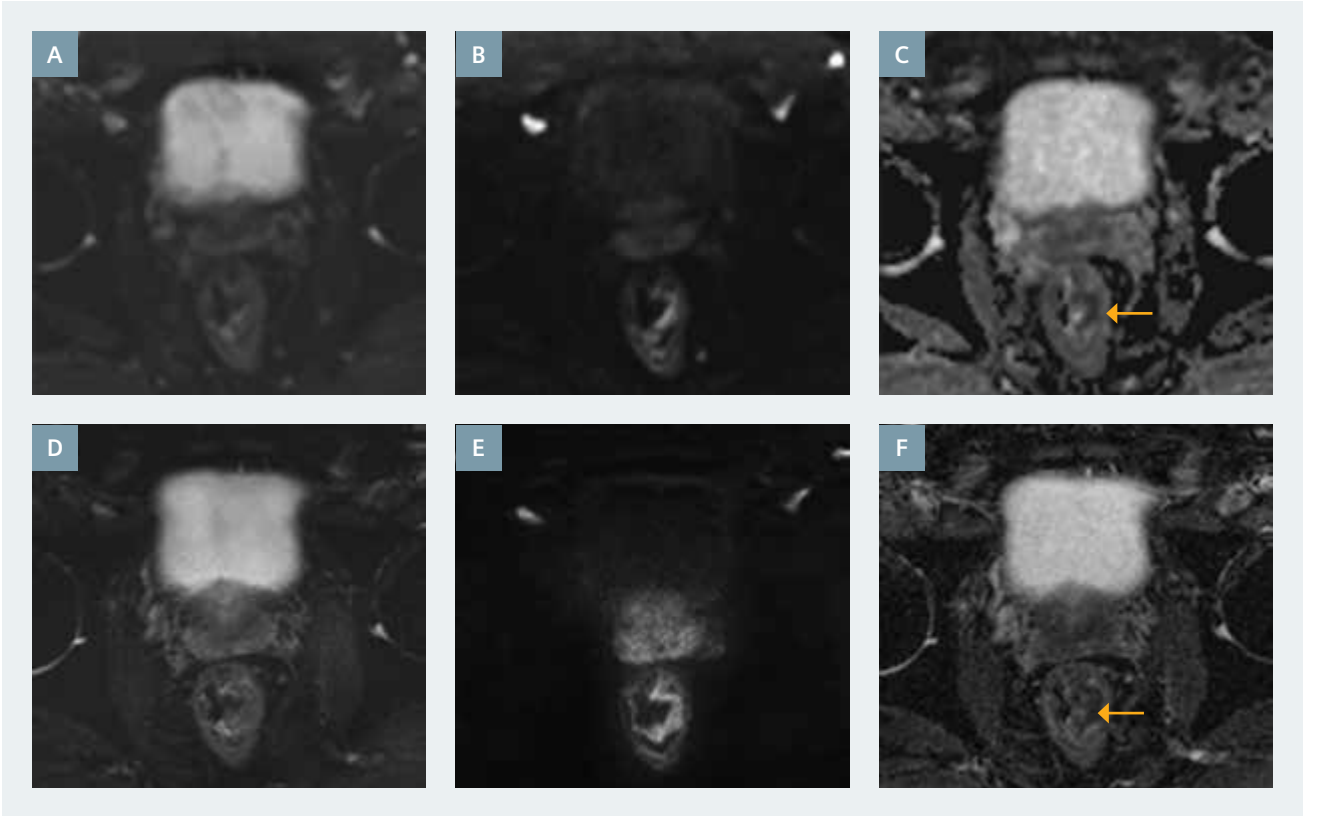

Figure 8 MAGNETOM Skyra
Clinical images courtesy of National University Hospital, Singapore.

Conclusion

RESOLVE enables robust, high-resolution, anatomically accurate diffusion MRI through the intelligent combination of readout-segmented EPI, parallel imaging, and 2D navigator echo. Compared to the conventional single-shot EPI DWI/DTI, RESOLVE provides susceptibility-reduced and sharper diffusion images, which are more robust to motion. The added value and popularity of diffusion MRI increase as the image quality improves, a clear result of advancing MR hardware and applications. As a new advance in diffusion MRI, RESOLVE significantly improves image quality, brings new levels of clarity to diffusion MRI in even the most difficult-to-image anatomies, and sets a new clinical standard in DWI and DTI. Improving the quality of the imaging sets the stage for improved clinical confidence, which can support faster exams, improved satisfaction among patients and their care providers, and expanded clinical services.

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