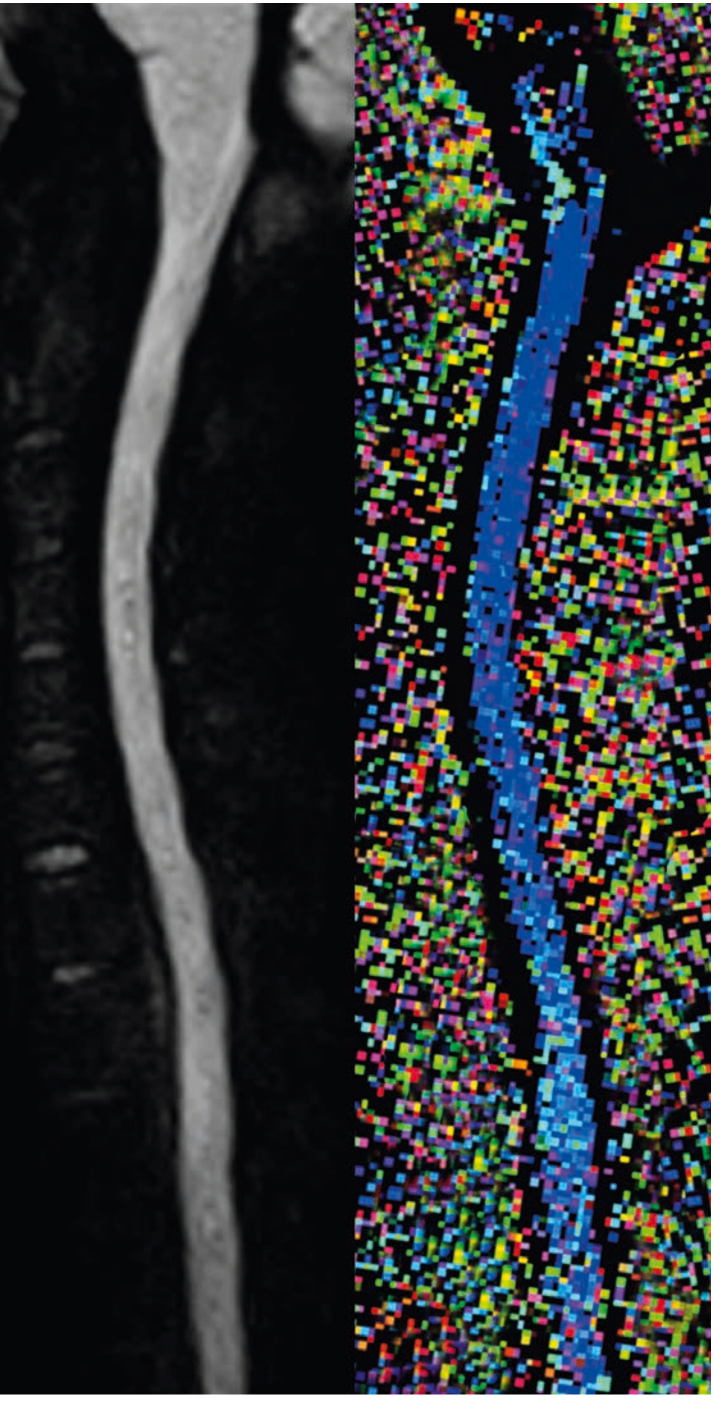
SIEMENS

siemens.com/RESOLVE

Outstanding DWI diagnostic performance with *syngo* RESOLVE



Diffusion-Weighted Imaging

The diffusion rate of water molecules in different tissues correlates with their physiological state, and may be altered in disease.

Diffusion-weighted imaging (DWI) enables visualization and measurement of abnormal diffusivity, revealing lesions which may go unnoticed with conventional anatomical MR or CT imaging alone. The practical clinical value of DWI is well established. Despite some challenges in certain body regions, particularly at higher field strengths, DWI is now broadly used in clinical routine.

syngo RESOLVE

syngo RESOLVE is a revolutionary new approach for obtaining high quality DWI images even in body regions strongly affected by susceptibility artifacts.

The clinical impact of *syngo* RESOLVE has been shown in a variety of examinations, including the brain, skull base, spine, breast, prostate, pelvis and rectum. *syngo* RESOLVE can be particularly useful in the evaluation of smaller lesions especially in regions strongly affected by susceptibility artifacts. Compared to alternative methods (see glossary, p.17), *syngo* RESOLVE brings the best balance of imaging speed and quality.

syngo RESOLVE – readout segmentation of long variable echo-trains

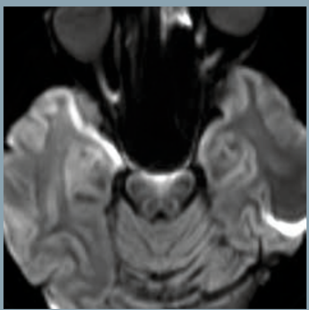
Experience a higher level of diagnostic confidence with sharp, high-resolution diffusion-weighted images largely free of geometric distortions.

Applications

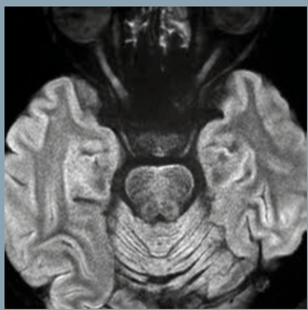
- Applicable in a variety of challenging body regions including brain, skull-base, spine, breast, pelvis and prostate

Advantages

- High-quality, high-resolution DWI and DTI
- Reduced susceptibility and blurring artifacts
- Insensitivity to motion-induced phase errors
- Reduced SAR in comparison to TSE-based methods



Conventional DWI

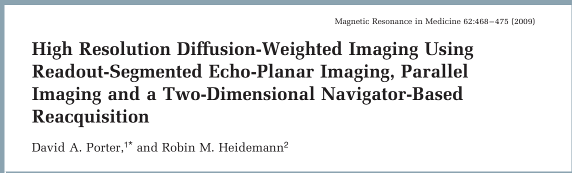


syngo RESOLVE

Nagoya University School of Medicine, Nagoya, Japan
MAGNETOM Verio

Technical specifications

- Readout-segmented, multi-shot EPI for reduced TE and encoding time
- Motion correction with 2D phase navigator and real-time image reacquisition for unusable data

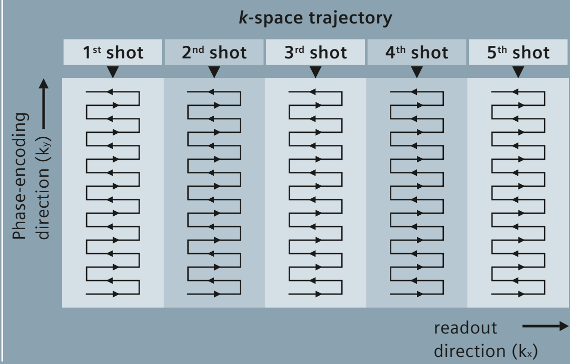


Magnetic Resonance in Medicine 62:468–475 (2009)

High Resolution Diffusion-Weighted Imaging Using Readout-Segmented Echo-Planar Imaging, Parallel Imaging and a Two-Dimensional Navigator-Based Reacquisition

David A. Porter,[1*] and Robin M. Heidemann[2]

Magn Reson Med, 62(2), 468-475, 2009

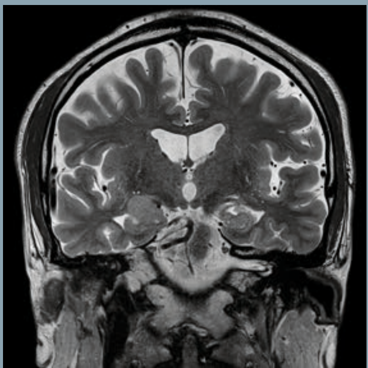


Neuroimaging

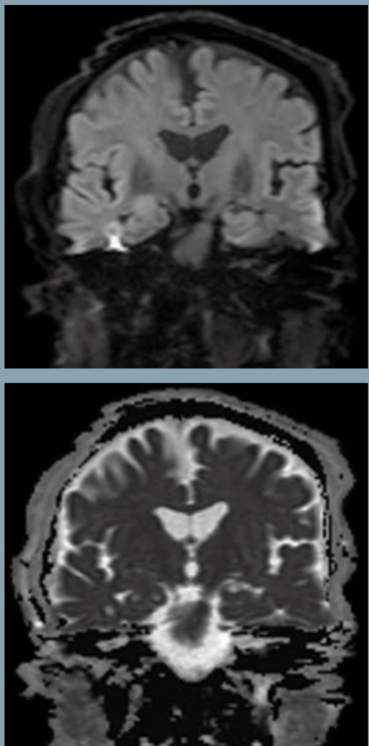
Hippocampal lesion

Conventional DWI

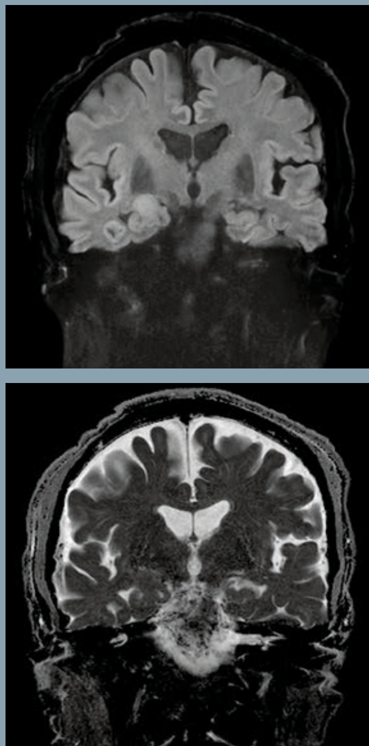
syngo RESOLVE



T2 TSE, GRAPPA 2, matrix 576, SL 2 mm



b1000 and ADC map, GRAPPA 2, matrix 160, TA 0.03 s/slice

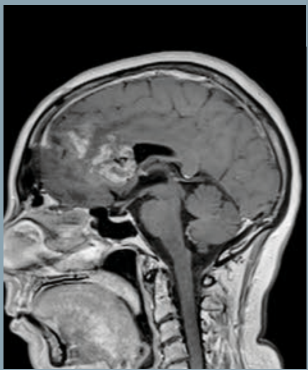


b1000 and ADC map, GRAPPA 2, matrix 384, TA 0.05 s/slice

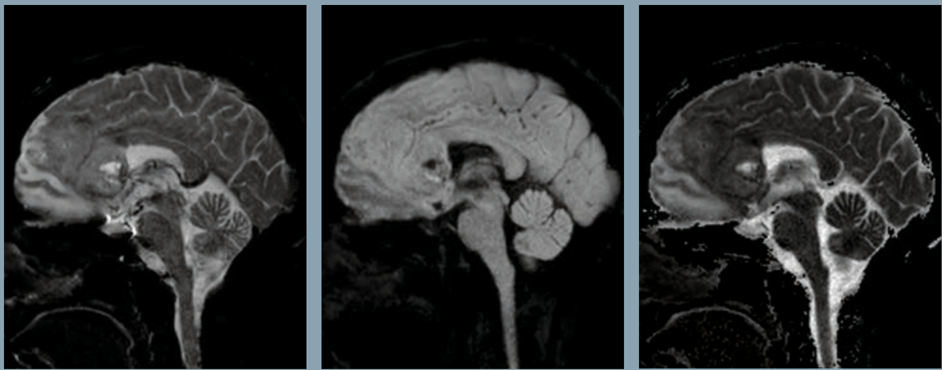
Ebara Hospital, Tokyo, Japan
MAGNETOM Trio, A Tim System

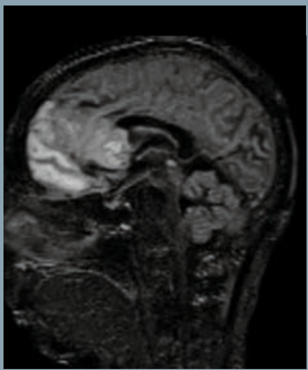
Brain tumor

T1 3D SPACE, GRAPPA 2,
post-contrast

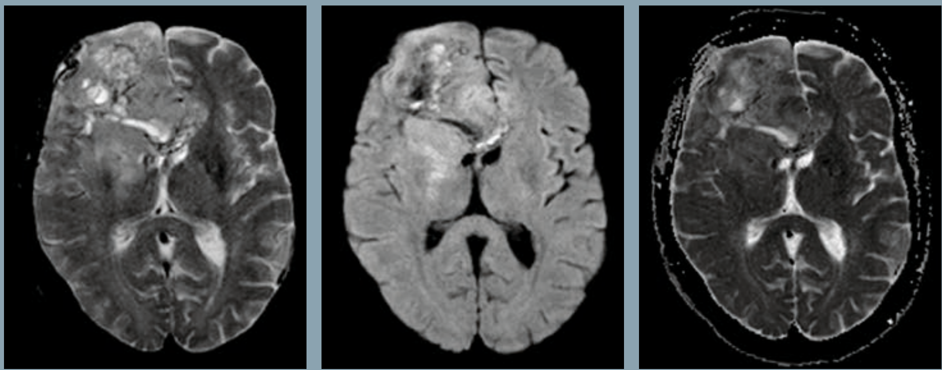


syngo RESOLVE, b0, b1000 and ADC map, GRAPPA 2, matrix 188, TA 5:25 min





3D SPACE DIR, GRAPPA 2



syngo RESOLVE, b0, b1000 and ADC map, GRAPPA 2, matrix 210, TA 5:18 min

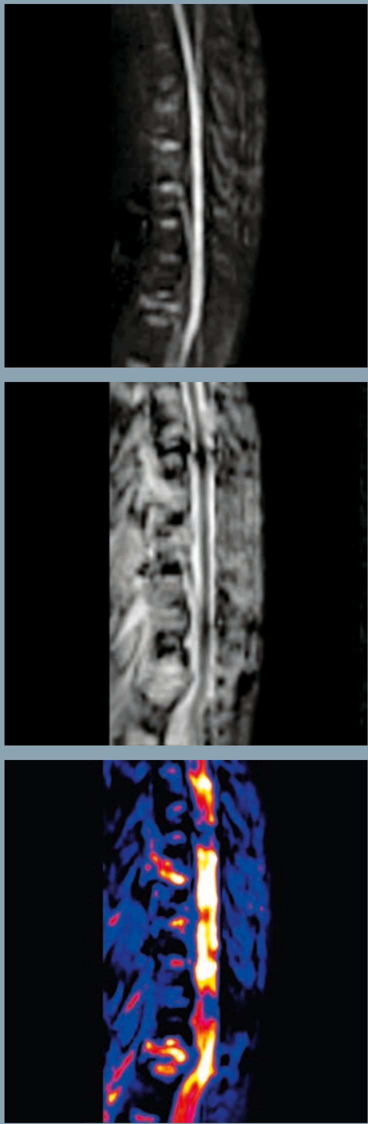
IRM Francheville, Perigueux, France
MAGNETOM Aera

Spine
Post accident,
TH6 and TH12 fracture

T2 TSE, GRAPPA 2,
matrix 384

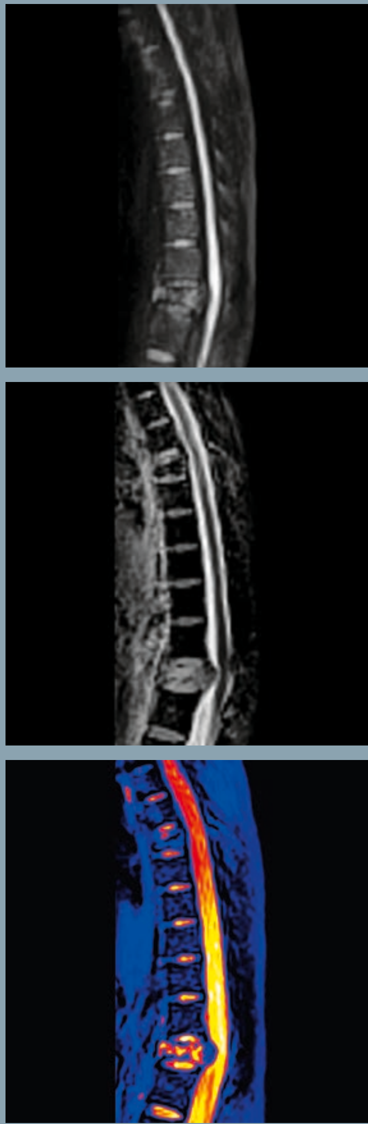
Singapore General Hospital, Singapore
MAGNETOM Avanto

Conventional DWI

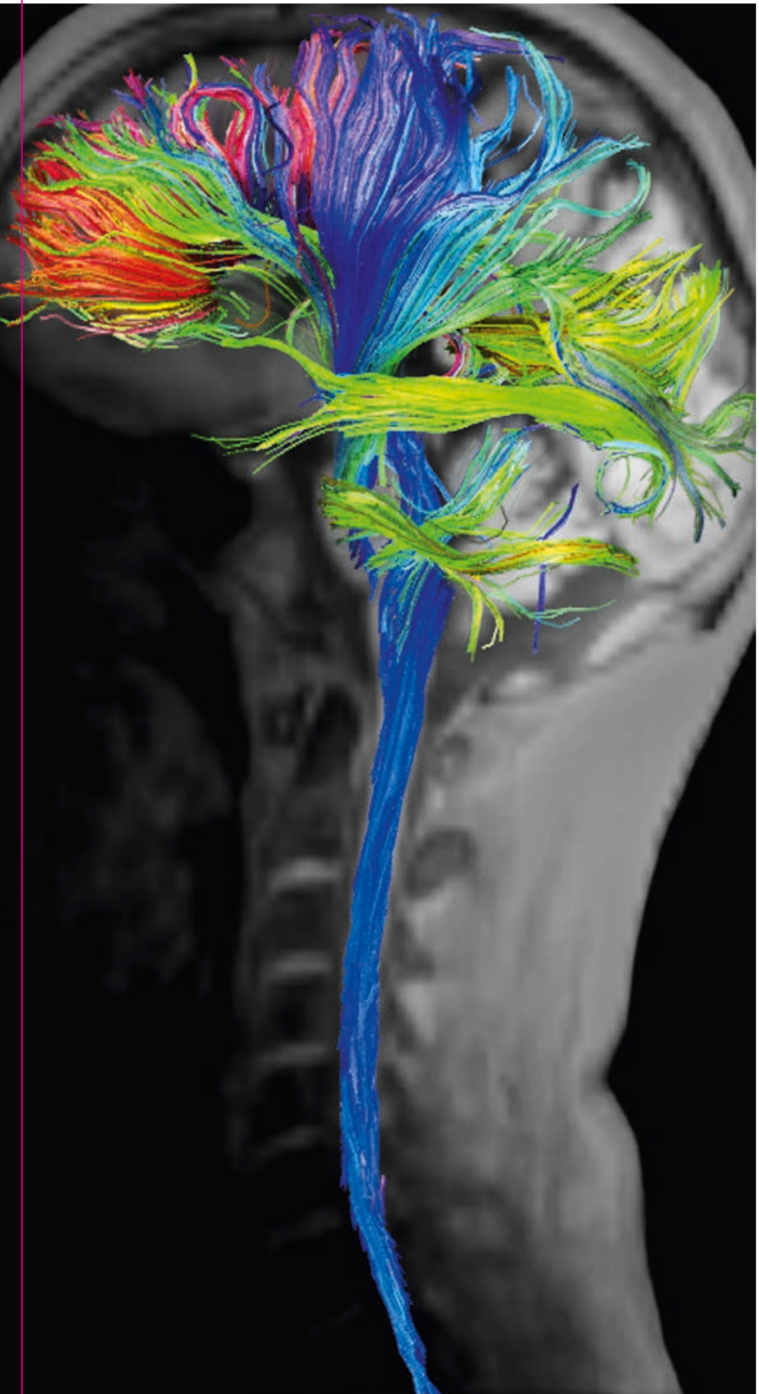


b650, ADC map and T1 TSE fused with b0 image, GRAPPA 2, matrix 128, TA 0.05 s/slice

syngo RESOLVE



b650, ADC map and T1 TSE fused with b0 image, GRAPPA 2, matrix 150, TA 0.02 s/slice



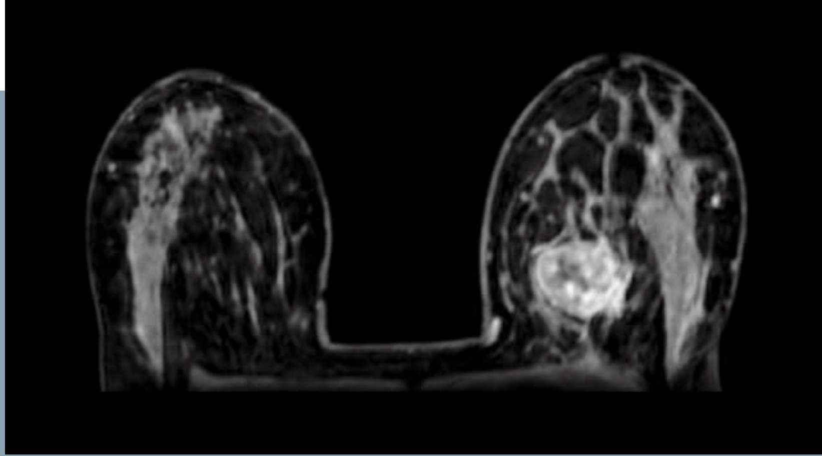
MGH Martinos Center, Charlestown, USA
MAGNETOM Trio, A Tim System

"*syngo* RESOLVE is a useful sequence for acquiring high-quality diffusion-weighted images thanks to the reduction of susceptibility distortion, reduction of T2* blurring, shorter TE (and hence high SNR), and robust correction for motion induced artifacts."[1]

Prof. Dr. Julien Cohen-Adad,
MGH Martinos Center, Charlestown, USA /
École Polytechnique de Montreal, QC, Canada

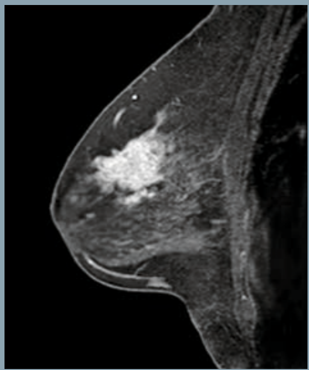
Body Imaging

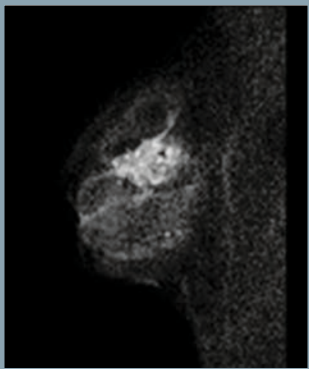
Breast Carcinoma



3D delVIEWS water excitation

3D dynVIEWS FatSat

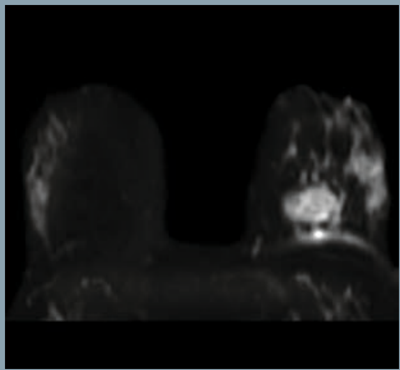


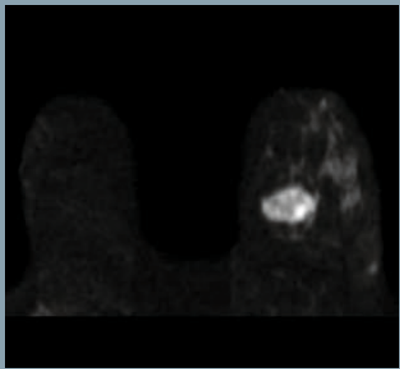


syngo RESOLVE, b1000

University Hospital, Kyoto, Japan
MAGNETOM Verio

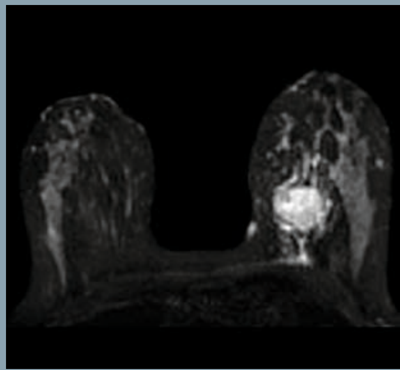
Conventional DWI

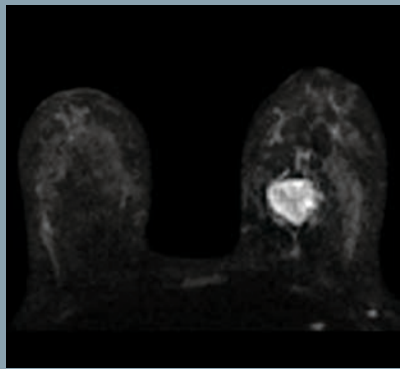




b0 and b850

***syngo* RESOLVE**



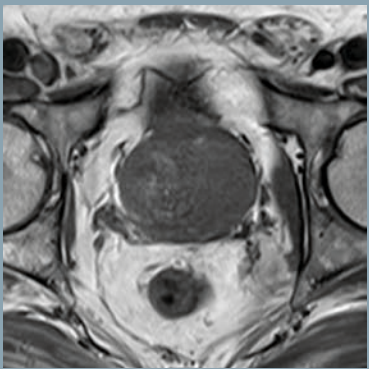


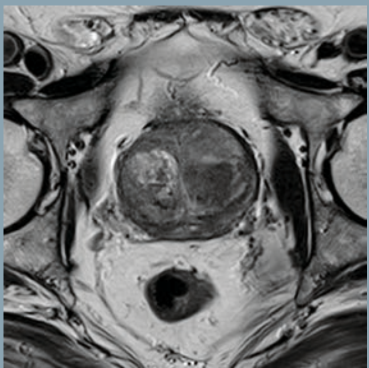
b0 and b850

AKH, Vienna, Austria
MAGNETOM Trio, a Tim system

Prostate Carcinoma

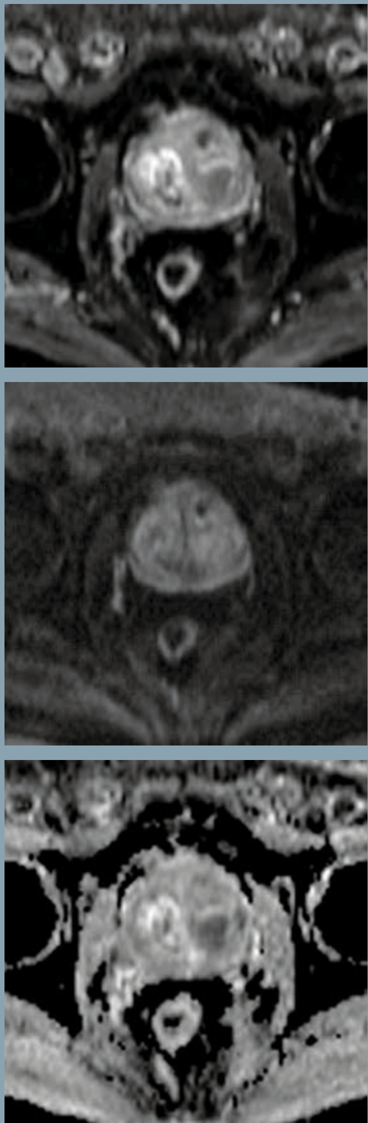
T1 TSE, GRAPPA 2





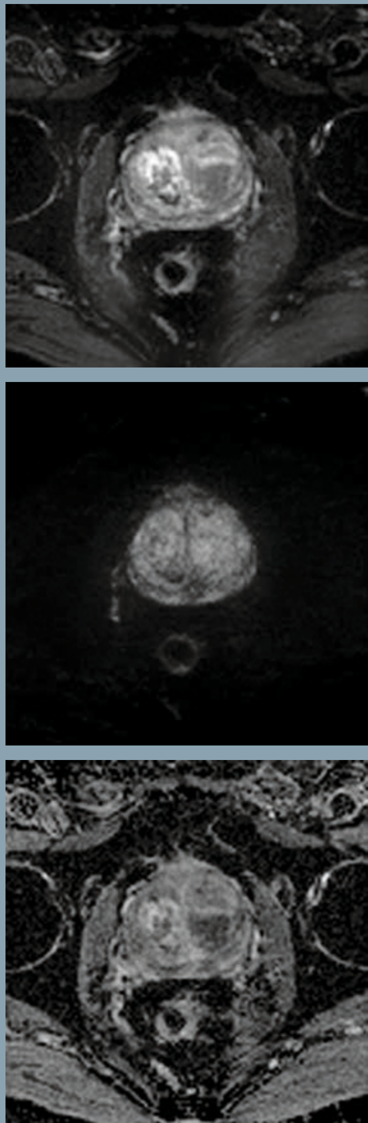
T2 TSE, GRAPPA 2

Conventional DWI



b0, b1000 and ADC map, GRAPPA 2, matrix 160, TA 0.04 s/slice

syngo RESOLVE



b0, b1000 and ADC map, GRAPPA 2, matrix 192, TA 0.03 s/slice

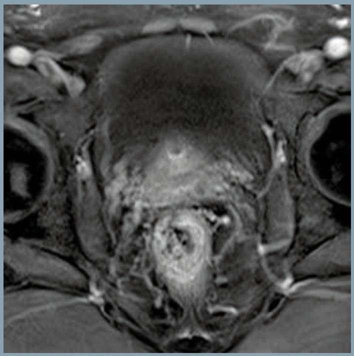
National University Hospital, Singapore
MAGNETOM Skyra

"*syngo* RESOLVE provides two very important advantages in comparison to conventional DWI sequences. First, RESOLVE gives ADC maps with significantly higher spatial resolution on a smaller FoV. Second, it eliminates the susceptibility artefacts at the interfaces between the endorectal coil, the rectal wall, and the prostate. This significantly improves diagnostic confidence in the peripheral zone, the key region of interest. Therefore, for examinations performed with the endorectal coil, *syngo* RESOLVE is one of the main tools to delineate the lesion contour and define the target for biopsy."[1]

Pr. Marc Lemort
Jules Bordet Institute
Brussels, Belgium

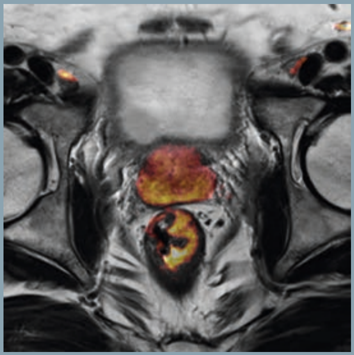
Rectal Carcinoma

T1 3D VIBE FatSat, post-contrast, GRAPPA 2, matrix 320



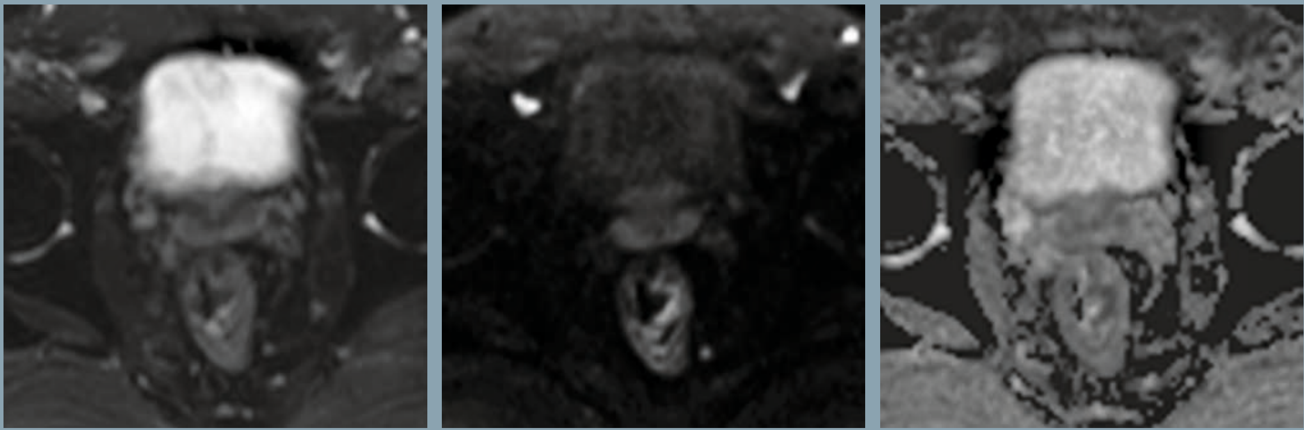
T2 TSE, GRAPPA 2

T2 TSE fused with RESOLVE b1000 image



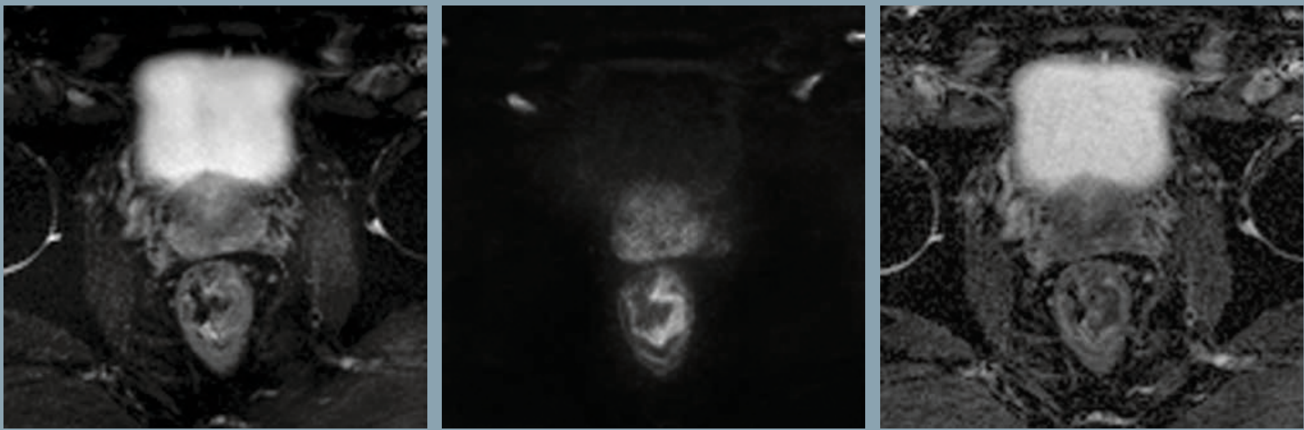
National University Hospital, Singapore
MAGNETOM Skyra

Conventional DWI



b0, b1000 and ADC map, GRAPPA 2, matrix 192, TA 0.03 s/slice

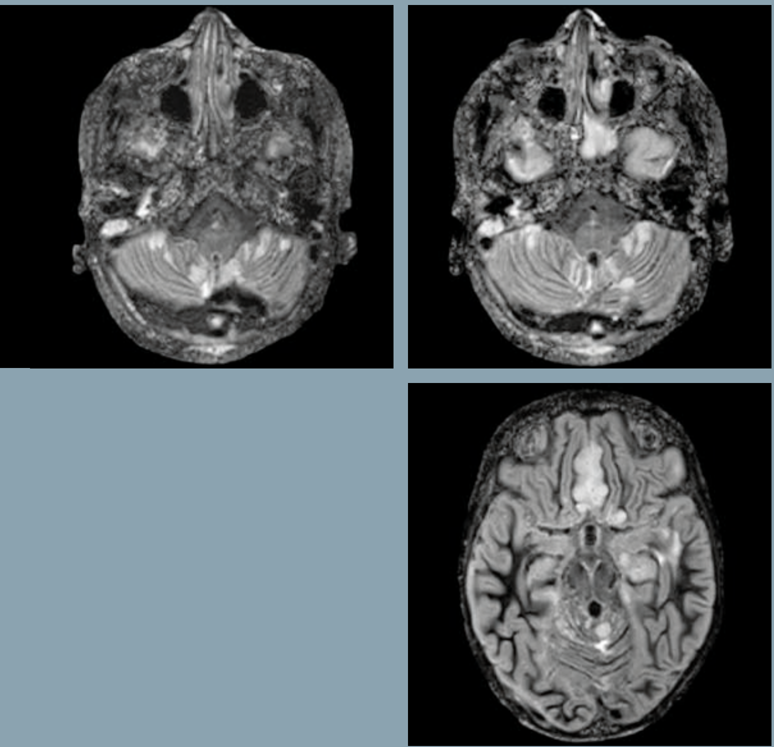
syngo RESOLVE



b0, b1000 and ADC map, GRAPPA 2, matrix 192, TA 0.03 s/slice

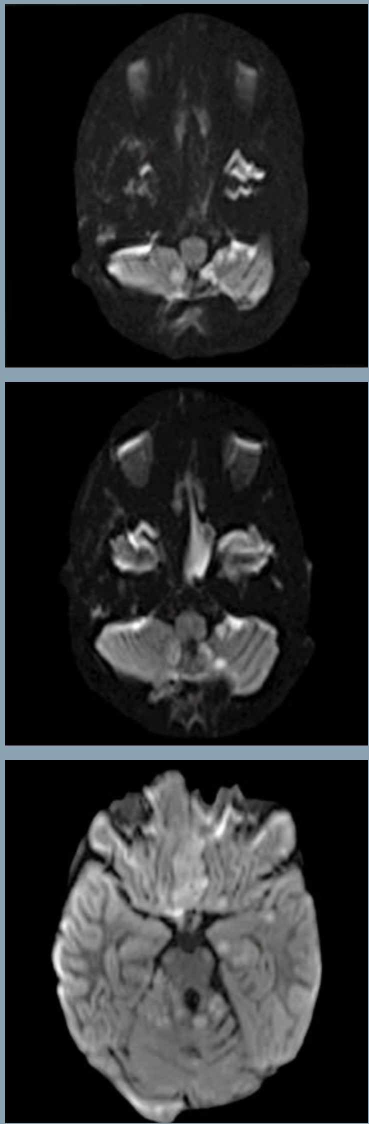
Pediatric Imaging[2]

Medulloblastoma
12 year old male



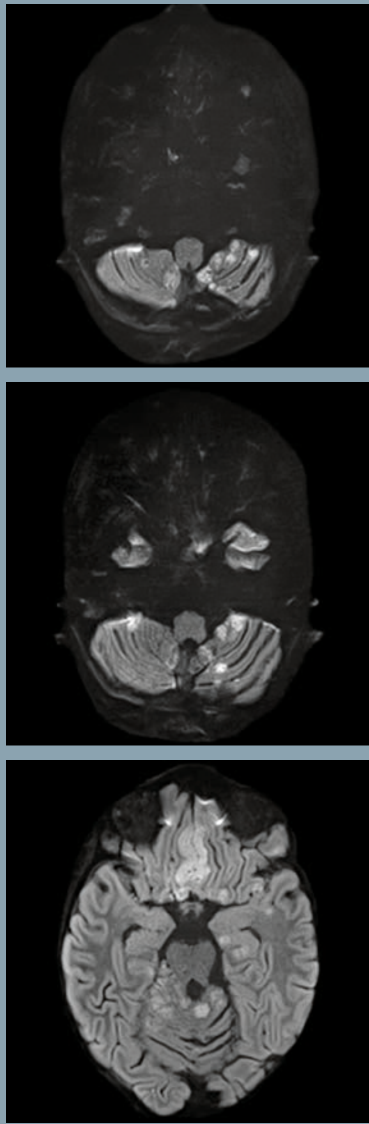
3D SPACE DIR, GRAPPA 2, thin MPR

Conventional DWI



b1000, GRAPPA 2, matrix 160,
TA 0.06 s/slice

syngo RESOLVE

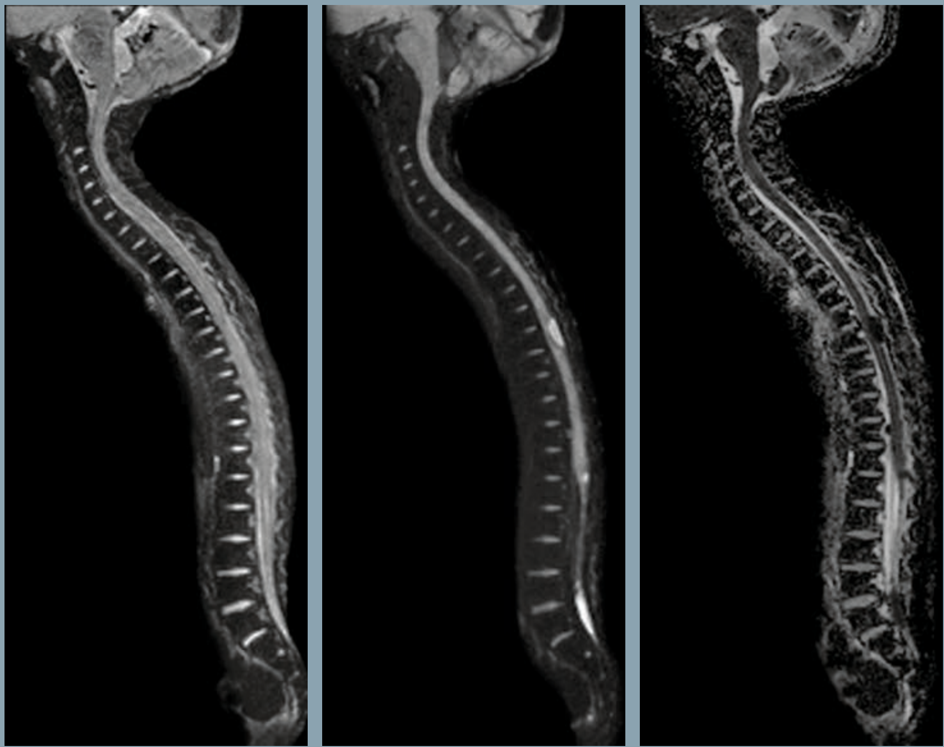


b1000, GRAPPA 2, matrix 224,
TA 0.03 s/slice

Children's MRI Centre, Royal Children's Hospital, Melbourne, Australia
MAGNETOM Verio

Drop metastases to the spine
2 year old female

T2 TSE, 2 steps composed



syngo RESOLVE, b5, b500 and ADC map, 2 steps composed, GRAPPA 2, matrix 192, 0.08 s/slice/step

Children's Healthcare of Atlanta at Scottish Rite, Atlanta, USA
MAGNETOM Avanto

Early clinical evidence

High-Resolution DWI in Brain and Spinal Cord with *syngo* RESOLVE[1]

Julien Cohen-Adad

Department of Electrical Engineering, Ecole Polytechnique de Montreal, QC, Canada
A. A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Harvard Medical School, Charlestown, MA, USA

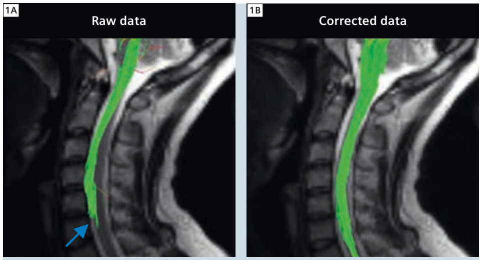
Abstract

In this paper we present some applications of the *syngo* RESOLVE[1] sequence that enable high-resolution diffusion-weighted imaging. The sequence is based on a readout-segmented EPI strategy, allowing susceptibility distortions and T2* blurring to be minimized. The RESOLVE[1] sequence can be combined with other acquisition strategies such as reduced field-of-view (FOV) and parallel imaging, to provide state-of-the-art tractography of the full brain and cervical spinal cord. The RESOLVE[1] sequence could be of particular interest for ultra high field systems where artifacts due to susceptibility and reduced T2 values are more severe. At all field strengths, the sequence promises to be useful in a number of clinical applications to characterize the diffusion properties of pathology with high resolution and a low level of image artifact.

1. Introduction

1.1. Diffusion-weighted imaging

Diffusion-weighted MRI makes it possible to map white matter architecture in the central nervous system based on the measurement of water diffusion [11]. The technique works by using MRI sequences that are sensitized to the microscopic motion of water molecules, which are in constant motion in biological tissues (Brownian motion). Using the well-known pulse sequence introduced by Stejskal and Tanner in 1965 [29], it is possible to quantify the extent of water displacement in a given direction. This sequence consists of magnetic field gradient pulses (diffusion-encoding gradients) that are applied before and after a 180° radiofrequency (RF) refocusing pulse. The first gradient pulse dephases the precessing nuclear spins that generate the signal in MRI. In the theoretical case of static molecules, the second gradient pulse completely rephases the spins and there is no attenuation due to the application of the gradients. However, if water molecules move during the application of this pair of gradients, spins are dephased and signal decreases as a function of the magnitude of the displacement, leading to a so-called diffusion-weighted signal. The magnitude by which the signal is weighted by diffusion is dictated by the so-called *b-value*, which depends on the length and amplitude of the applied diffusion-encoding gradients, as well as the duration between the first and the second gradient pulse (also called diffusion time). By applying diffusion gradients in various directions (e.g., 20 directions equally sampled on a sphere), it is possible to estimate the rate and direction of water diffusion. For example in pure water, molecules diffuse equally in all directions, hence the diffusion is described as *isotropic*. Conversely, in mesenchymal structures such as the white matter or muscles, water diffuses preferentially along the direction of the fiber. In such a case, the diffusion is *anisotropic* [3].



1 Tractography in a healthy subject, overlaid on a distortion-free anatomical image (fast spin echo). **(1A)** shows tractography performed on the raw data (i.e., without correction). **(1B)** shows tractography performed on the same dataset, after distortion correction using the reversed-gradient technique [13]. A false apparent interruption of the tracts is observed on the data hampered by susceptibility distortions. Acquisition was performed using the standard EPI sequence with the following parameters: sagittal orientation, TR/TE = 4000/86 ms, 1.8 mm isotropic, R = 2 acceleration. Tractography was seeded from a slice located at C1 vertebral level.

[1]The software is pending 510(k) clearance, and is not yet commercially available in the United States and in other countries.

Journal of Clinical Imaging Science
TECHNICAL INNOVATIONS

Echo Planar Diffusion-Weighted Imaging: Possibilities and Considerations with 12- and 32-Channel Head Coils

John N Morelli, Megan R Saettele[1], Rajesh A Rangaswamy, Lan Vu, Clint M Gerdes, Wei Zhang[2], Fei Ai[3]
Scott and White Hospital/Texas A&M HSC, [1]University of Missouri - Kansas City/St. Luke's Hospital, USA, [2]Tongji Hospital, Huazhong University of Science and Technology, [3]Cancer Center of SUN YAT-SEN University, Republic of China

J Clin Imaging Sci, 2(1), 1-6, 2012

"The utility of single-shot (ss) and an approach to readout-segmented (rs) echo planar imaging (EPI) are examined. Substantial image quality improvements are found with rs-EPI."

Eur Radiol
DOI 10.1007/s00330-012-2620-1
NEURO

Benign versus metastatic vertebral compression fractures: combined diffusion-weighted MRI and MR spectroscopy aids differentiation

Helmut Rumpel · Yi Chong · David A. Porter · Ling L. Chan

Eur Radiol, 23(2), 541-550, 2013

"Diffusion-weighted read-out-segmented echo-planar imaging improves spinal image quality."

TECHNICAL NOTE

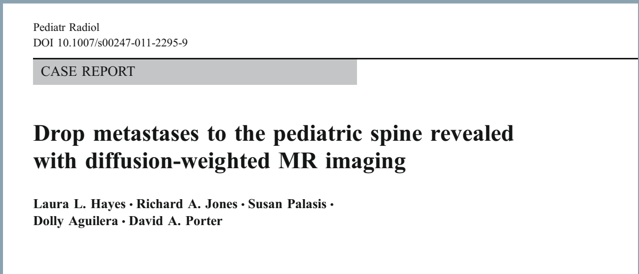
Anatomical Details of the Brainstem and Cranial Nerves Visualized by High Resolution Readout-segmented Multi-shot Echo-planar Diffusion-weighted Images using Unidirectional MPG at 3T

Shinji NAGANAWA[1*], Masahiro YAMAZAKI[1], Hisashi KAWAI[1], Michihiko SONE[2], Tsutomu NAKASHIMA[2], and Haruo ISODA[3]

Departments of [1]Radiology and [2]Otorhinolaryngology, Nagoya University Graduate School of Medicine 65 Tsurumai-cho, Showa-ku, Nagoya 466-8550, Japan
[3]Department of Radiological Technology, Nagoya University School of Health Sciences
(Received April 15, 2011; Accepted June 1, 2011)

Magn Reson Med Sci, 10(4), 269-275, 2011

"We compared diffusion-weighted imaging (DWI) with readout-segmented multi-shot echo-planar imaging (rs-EPI) and single-shot EPI, both using unidirectional motion-probing gradient, in 10 patients for visualization of the anatomical structures in the brainstem. DWI by rs-EPI was significantly better than DWI by single-shot EPI for visualizing the medial longitudinal fasciculus, lateral lemniscus, corticospinal tract, and seventh/eighth cranial nerves and offered significantly less distortion of the brainstem."


Pediatr Radiol
DOI 10.1007/s00247-011-2295-9

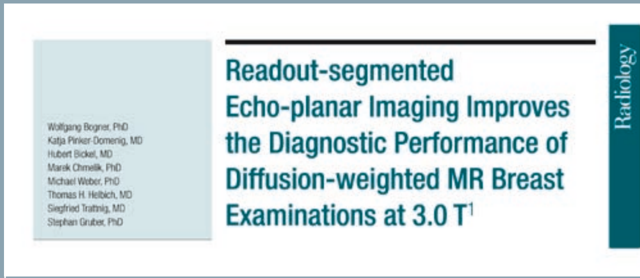
CASE REPORT

Drop metastases to the pediatric spine revealed with diffusion-weighted MR imaging

Laura L. Hayes · Richard A. Jones · Susan Palasis · Dolly Aguilera · David A. Porter

Pediatr Radiol, 42(8), 1009-1013, 2012

"DWI of the spine has not been clinically useful in children because of susceptibility artifacts and lack of spatial resolution. A new technique, readout-segmented echo planar imaging (EPI), has improved these images, allowing for identification of hypercellular drop metastases."


Wolfgang Bogner, PhD
Katja Pinker-Domenig, MD
Hubert Bickel, MD
Marek Chmelik, PhD
Michael Weber, PhD
Thomas H. Helbich, MD
Siegfried Trattnig, MD
Stephan Gruber, PhD

Readout-segmented Echo-planar Imaging Improves the Diagnostic Performance of Diffusion-weighted MR Breast Examinations at 3.0 T[1]

Radiology

Radiology, 263(1), 64-76, 2012

"Readout-segmented echo-planar imaging reached a higher diagnostic accuracy for the differentiation of benign and malignant breast lesions."

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siemens.com/magnetom-world

Glossary: Diffusion-weighted techniques

syngo **RESOLVE (readout-segmented EPI)**	A readout-segmented, multi-shot EPI sequence where the k-space trajectory is divided into multiple segments in the readout direction, reducing TE and encoding times to increase image quality. *syngo* RESOLVE provides high-quality, high-resolution, distortion-minimized DWI of challenging body regions, including the skull base, spine, breast and pelvis. High-resolution DTI imaging can also be achieved for the brain and spine. Motion correction is performed using a 2D navigator to correct for motion-induced, non-linear phase errors. Robust image quality is further enhanced by the use of a real-time navigator-based reacquisition technique to replace uncorrectable data with severe phase errors. Imaging can be performed in all orientations and the sequence is compatible with parallel imaging, providing a further reduction in susceptibility-based distortions.
Single-shot EPI	The sequence conventionally used in clinical imaging which samples the entire k-space in a single readout. While fast and relatively motion-insensitive, it is prone to susceptibility artifacts at tissue interfaces, especially at higher field strengths. Spatial resolution is limited by the T2* decay during the long readout time. Image distortion makes it particularly difficult to achieve diagnostic DWI of the spine.
Phase encode segmented EPI (interleaved EPI)	Multi-shot EPI with segmentation applied in the phase-encoding direction, so that all readout points are sampled at each shot, but with a reduced number of phase encoding points. While the sequence can provide higher spatial resolution and imaging in all orientations, the sampling scheme used cannot be easily combined with 2D, non-linear, navigator phase correction. As a consequence, when combined with diffusion-weighting, the sequence is prone to motion-induced aliasing artifacts. Spine DWI is of insufficient image quality and it remains to be seen if high quality DTI can be enabled.
BLADE diffusion (TSE-based)	For this sequence, the k-space is sampled in a radial fashion. Images may be high-resolution and relatively motion-insensitive. However, the acquisition time may be comparatively long and imaging can only be acquired in the axial plane. Spine DWI is of insufficient image quality and it remains to be seen if high quality DTI can be enabled.

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[1] The statements by Siemens' customers described herein are based on results that were achieved in the customer's unique setting. Since there is no "typical" hospital and many variables exist (e.g., hospital size, case mix, level of IT adoption) there can be no guarantee that other customers will achieve the same results.

[2] MR scanning has not been established as safe for imaging fetuses and infants under two years of age. The responsible physician has to decide about the benefit of the MRI examination in comparison to other imaging procedures.

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