

# High-Resolution, Isotropic-Voxel Acquisition Technique Improves Quality and Utility of Diffusion-Weighted and Diffusion Tensor Imaging

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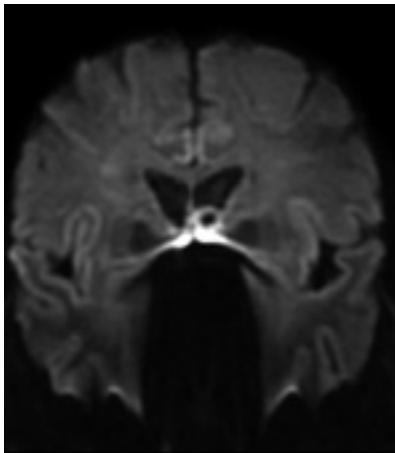
## Introduction

Image quality in diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) tends to be deteriorated by echo planar imaging (EPI)-related image distortions and artifacts, particularly in the case of coronal images and at high fields of 3.0T, even when a parallel imaging technique is applied. This disadvantage prevents clinicians from assessing changes in structures adjacent to the skull base, such as the medial temporal lobe and frontal base. Partial volume effects in DWI/DTI also affect the accuracy in the calculation of diffusion parameters and in the generation of tractographs. A new DWI/DTI technique enables the generation of high-resolution isotropic-voxel "volume" datasets that can reduce partial volume effects and susceptibility-related distortions/artifacts near the skull base. Further, we demonstrate the clinical efficacies of images generated from these volume datasets using multiplanar reconstruction, volume rendering, color-coded axonography and DTI tractography.

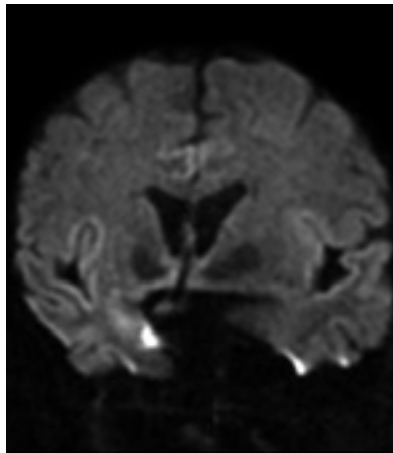
## Volume Diffusion Imaging Technique

To obtain high-resolution isotropic-voxel DWI/DTI data, we utilized a simple two-dimensional (2D) acquisition approach, instead of a three-dimensional (3D) approach, with ultra thin sections as in the case of multidetector-row computed tomography (MDCT). Images were obtained on a Signa® HD 3.0T with an eight-channel head coil using the following pulse sequences: axial single-shot spin-echo EPI; repetition time/echo time, 12000–17000/62.5; 3 or 6 motion-probing gradient (MPG) directions with a b value of 1000 s/mm<sup>2</sup>; a matrix size of 128 x 128, a field of view of 20 cm, a slice thickness of 1.6 mm with no interslice gaps, resulting isotropic voxels of 1.6 x 1.6 x 1.6 mm; 4 averaged; an array spatial sensitivity encoding technique (ASSET), reduction factor of 2; and 80 to 90 slices for the coverage of the entire brain with an acquisition time ranging from 6 min, 24 sec to 8 min, 30 sec.<sup>1,2</sup>

Coronal DWI Asset (-)



Coronal DWI Asset (+)



Volume DWI (MPR)

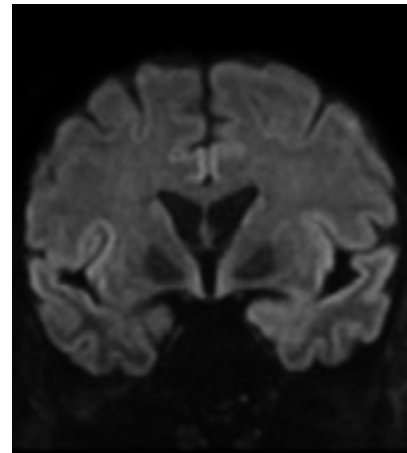


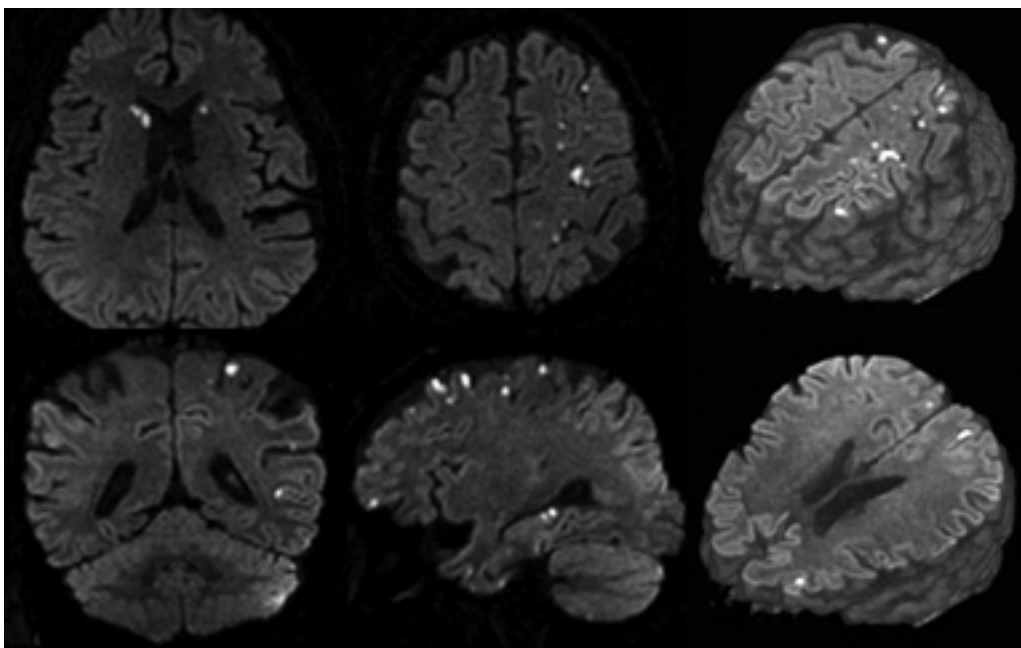
Figure 1. Volume DWI can decrease geometric distortion and susceptibility artifacts in coronal images.

## Advantages of Volume Diffusion Imaging

The whole-brain high-resolution isotropic-voxel DWI/DTI acquisition technique using ultra thin axial sections has several advantages over conventional DWI/DTI. These include: reduction of geometric distortions and susceptibility artifacts near the skull base; decrease in partial volume effects that can affect the accuracy in the calculation of quantitative diffusion parameters and in the delineation of tractographs; and capability of multiplanar reconstruction and further image processing. Among them, geometric distortions in the craniocaudal direction and susceptibility artifacts near the skull base on coronal images are dramatically decreased owing to the thin-slice axial images obtained with this technique.<sup>1</sup> On the coronal images generated from the volume DWI data, as compared with conventional coronal DWI, the structures of the medial temporal lobe and frontal base showed minimal deformities and tolerable susceptibility artifacts with preservation of the in-plane spatial resolution (Figure 1).

## Clinical Applications of Volume Diffusion Imaging

The volume diffusion imaging technique enables sophisticated multimodal interactive visualization and interpretation, which has been nearly impossible to achieve using conventional DWI/DTI. Once the volume dataset is obtained, we can observe trace maps, apparent diffusion coefficient (ADC) maps, fractional anisotropy (FA) maps and color-coded axonography images of patients with neurological conditions such as stroke, brain tumors or degenerative disorders by using paging, multiplanar reconstruction or volume-rendering techniques (Figures 2 and 3).



**Figure 2.** Volume DWI enables multiplanar reconstruction and further postprocessing, such as volume rendering (Provided by Okayama Kyokuto Hospital).



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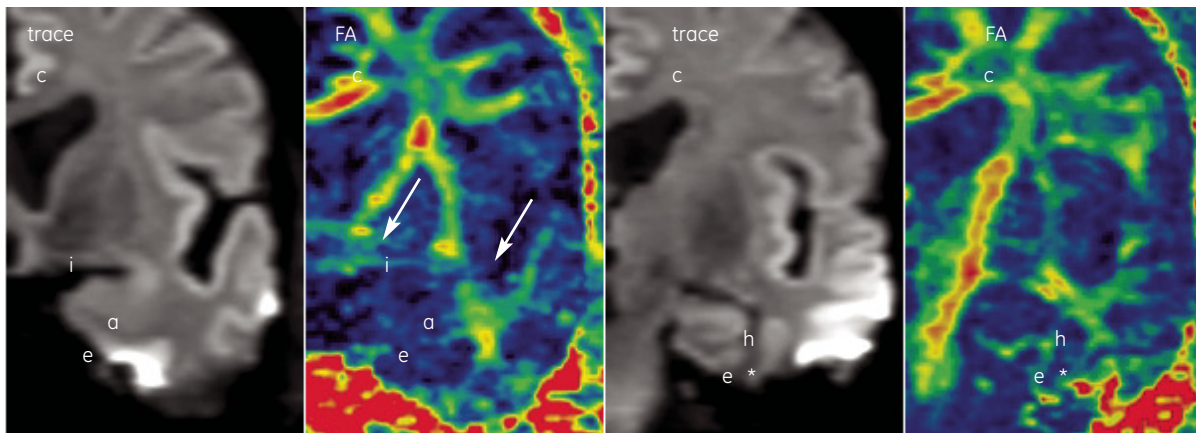
Makoto Sasaki, M.D., is Associate Professor, Advanced Medical Research Center, Iwate Medical University, School of Medicine. He received his medical degree and doctorate of medical sciences from Iwate Medical University. Dr. Sasaki currently serves as trustee of the Japanese Society of Magnetic Resonance in Medicine and the Japanese Society of Neuroradiology. He is an active member of the Japan Radiological Society, ISMRM, RSNA, Japan Stroke Society, Japanese Society of Neurology and Japanese Society for Detection of Asymptomatic Brain Diseases.

Dr. Sasaki plays an important role in the standardization of the stroke imaging through ASIST-Japan (Acute Stroke Imaging STandardization group Japan) activities (<http://assist.umin.jp/index-e.htm>). He is also leading to develop a neuromelanin-sensitive MRI technique that can visualize alteration of catecholamine nuclei in mental disorders. A Certificate of Merit was awarded to him and his colleagues for volume diffusion imaging (NR4667) and neuromelanin imaging (NR4704) at RSNA2006.

### About Iwate Medical University, Morioka, Iwate Pref

Iwate Medical University, founded in 1928, and its affiliate hospital (1051 beds) has been the core healthcare and research center in northern Japan through the establishment of several key facilities, including Memorial Heart Center (1997) and Advanced Medical Research Center (1999). The Advanced Medical Research Center, headed by Dean and Chairman Prof. Akira Ogawa, was established primarily for the investigation of neuroscience and neuroimaging, and has made significant contributions to research of the brain with High Field 3.0T MRI and PET.

Figure 3. Volume DWI/DTI can visualize minute structures that belong to the limbic system.



a: amygdala, c: cingulum, e: entorhinal cortex, h: hippocampus, i: substantia innominata, \*parahippocampal white matter containing the perforant path, arrows: anterior commissure.

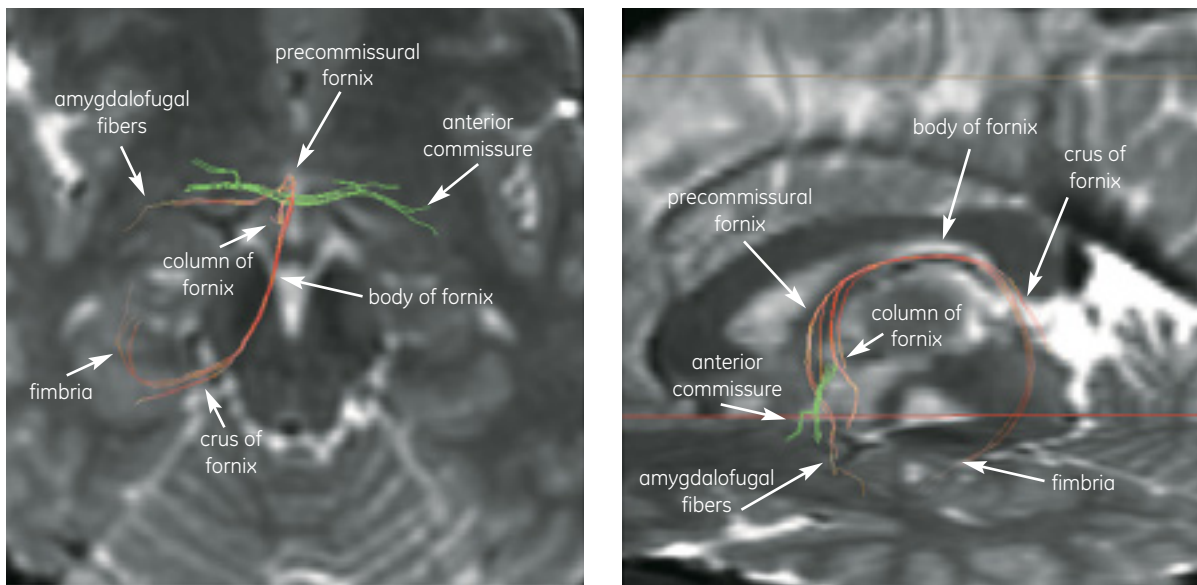


Figure 4. Multimodal volume neuroimaging combining 3D-FSPGR, Cube™ (T2WI and FLAIR), and volume DTI can bring about a paradigm shift from a 2D to a 3D approach in clinical neuro-magnetic resonance imaging.

The precise quantitative evaluation of minute structures of the limbic system is a promising application of the volume diffusion technique. The ADC or FA in small limbic structures, such as the hippocampus, entorhinal cortex and substantia innominata, can be measured because the increase in spatial resolution and the decrease in susceptibility distortions/ artifacts synergistically improve image quality (Figure 3). In addition, the precision of the segmentation of small limbic

fibers, such as the fornix, using DTI tractography can be improved; this can influence the accuracy of the estimation of the ADC and FA in these fibers.<sup>2</sup> The volume diffusion technique can be useful for detecting subtle changes in the small limbic structures in patients with early Alzheimer's disease, temporal lobe epilepsy or other disorders that have barely been assessed by conventional DWI/DTI techniques.

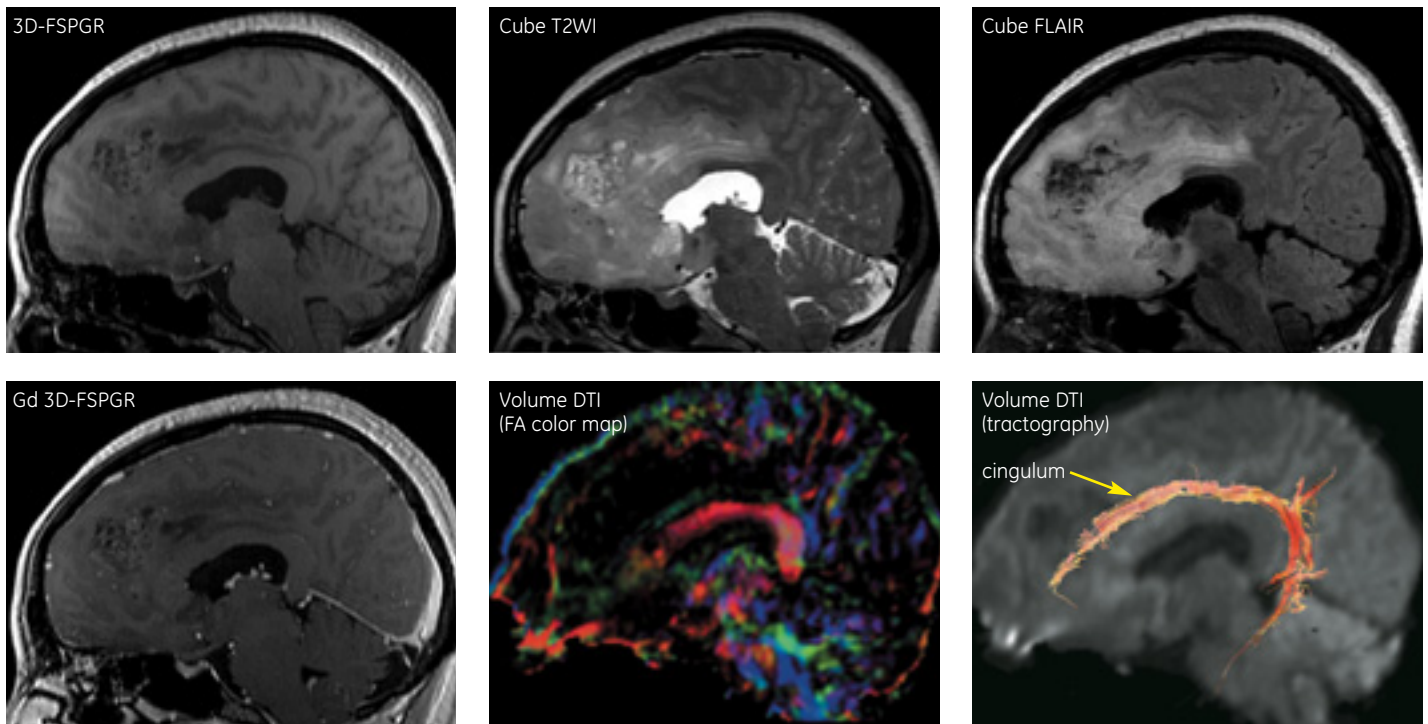


Figure 5.

Further, we believe that even in routine clinical practice, conventional neuroimaging protocols that primarily utilize 2D imaging at 3.0T can be replaced by an advanced protocol involving the acquisition of multimodal volume data sets, including 3D fast spoiled gradient-recalled acquisition in the steady state (3D-FSPGR), fast spin-echo with extended echo-train acquisition (Cube) and volume DWI/DTI (Figure 4).

## Conclusion

Volume diffusion imaging with high-resolution, isotropic voxels is effective in avoiding partial volume effects and EPI-related distortions and artifacts that are particularly prominent in the coronal directions and at high fields. It also enables the elucidation of subtle abnormalities in minute brain structures in central nervous system disorders using multiple diffusion parameter maps visualized by multiplanar reconstruction, tractography and further image processing. ■

### Acknowledgement

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### References

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2. Fujiwara S, Sasaki M, Kanbara Y, et al. Feasibility of 1.6-mm isotropic voxel diffusion tensor tractography in depicting limbic fibers. *Neuroradiology* 2007 (in press)