# Diffusion Weighted Imaging with Whole Brain Coverage and Sub-Microliter Voxels

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**Introduction:** Achieving voxel sizes that are smaller than 1 μL is common in structural scans of the human brain. Typically these scans use T1, T2, or proton density weighting for contrast. In this work, a method is proposed that enables resolutions similar to common structural scans, but with a diffusion weighting for contrast. This could be useful to reduce partial volume effects from CSF regions in sulci which are typically less than 1 mm thick and to resolve gray matter which can be less than 2mm thick, especially since the thickness of these structures is known to change with age. The developed method provides new opportunities for researchers and clinicians to investigate the human brain with a contrast mechanism that was traditionally limited to lower resolutions. Images with 0.8 mm isotropic voxels, giving a voxel volume of 0.512 μL, are shown for the whole brain of a healthy subject from a clinical 3 T system.

**Methods:** Diffusion weighted imaging has been limited to low resolutions due to limitations in SNR and artifacts when using multi-shot techniques. In order to achieve images with voxels smaller than 1 μL, whole brain coverage, and a well-defined diffusion encoding scheme, a 3D multislab approach can be used [1]. This approach allows the standard pulsed gradient spin echo (PGSE) diffusion weighting scheme to be used, but allows for a more SNR-efficient acquisition than is possible in equivalent 2D imaging, allowing higher resolutions to be achieved.

The imaging acquisition for this work had an isotropic resolution of 0.8 mm and a FOV of 24 cm. In the slab encoding direction, 12 slabs were acquired each 12.8 mm thick and were overlapped with neighboring slabs by 25%, resulting in 115.2 mm of coverage in the slab encoding direction. K-space encoding was performed using a stack of constant density spirals with an 8 shot in-plane spiral being acquired for each of the 16 phase encoding steps, resulting in 128 shots for each slab. A separate 3D low resolution navigator, also using a stack of spirals trajectory was acquired after a second refocusing echo for motion correction [2]. The acquisition used a b-value of 1000 s/mm$^2$ and a TE of 73 for imaging data and a TE of 174 for navigator data. Data was acquired on a Siemens 3 T Trio with a 32 channel head coil. Cardiac gating was used with 2 slabs acquired during each R-R interval. For a person with a 1 second R-R interval this acquisition would take 12 minutes and 48 seconds. For comparison, the same acquisition strategy was used to acquire 1.25 mm isotropic resolution on the same subject.

Images were reconstructed using iterative techniques with SENSE and field correction [3].Field correction is desirable as it allows for longer data readouts to be used, allowing for spirals with fewer interleaves to be used, shortening the overall acquisition time. The field map and coil sensitivity information were acquired from a separate scan.

**Results:** Figure 1 shows several views of the high resolution diffusion weighted image obtained using the proposed methodology. The images show excellent diffusion weighted contrast. A comparison to a 1.25 isotropic resolution scan is also shown.

**Discussion:** The proposed acquisition strategy was able to achieve diffusion weighted images with a voxel size of 0.512 μL. The resulting image provides great contrast between white matter, gray matter, and CSF. Comparing the 0.8mm scan to a 1.25 mm scan showed a significant reduction of partial volume effects. The reduction in partial volume effects can be observed even in this comparison of 0.8 mm with 1.25 mm which are both much higher resolution than is typically used for diffusion imaging. Continued refinements of the technique may lead to higher resolutions and reduction of imaging artifacts. This high resolution imaging scheme has the potential to open up new possibilities for studying fine structures in the brain using diffusion weighted imaging.

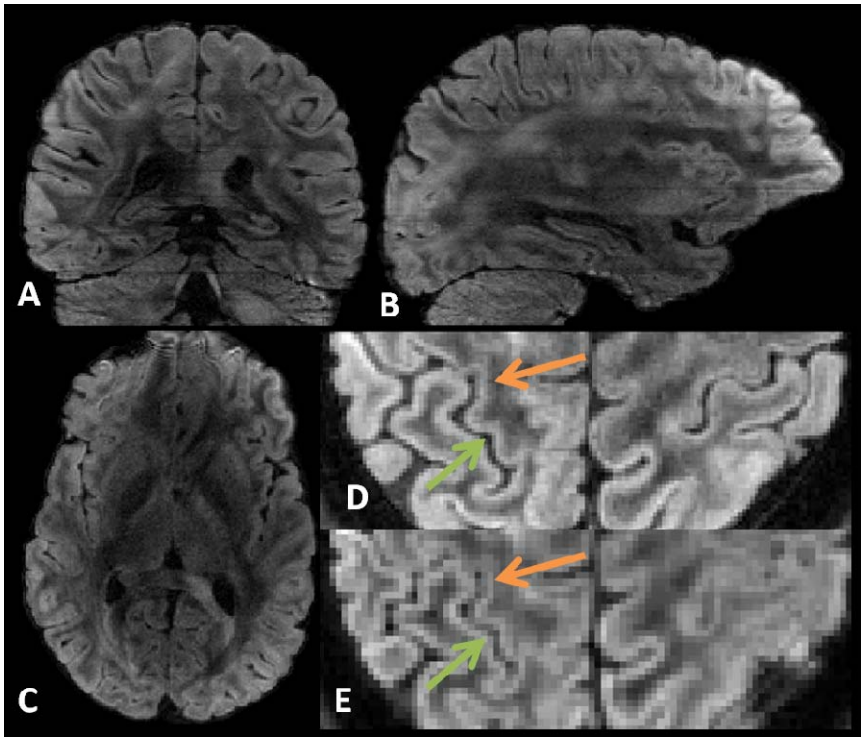


**Figure 1:** 0.8 mm isotropic resolution diffusion weighted image with a b-value of 1000 s/mm$^2$. (A) Coronal, (B) sagittal, (C) axial. A comparison of (D) 0.8 mm to (E) 1.25 mm for the same slice is shown. The green arrows show a sulcus that is much clearer at the higher resolution while the orange arrow shows an area where white and gray matter separation is more obvious.

**References:***[1] JL Holtrop, et al., ISMRM, 2012, p.1881; [2] A. T. Van, et al. IEEE Transactions on Medical Imaging, vol. 30, pp. 1933-1940, 2011. [3]* J Gai, *et al.*, *ISMRM*, 2012, p.2550;

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