Diffusion Weighted Imaging with a Limited Field of View using Interleaved Multi-Slices Inner-Volume-Imaging DW HASTE

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INTRODUCTION: Diffusion weighted MRI (DWI), using single-shot 2D diffusion weighted-EPI (2D ss-DWEPI), is limited to intracranial applications far from the sinuses and bony structures, due to the severe geometric distortions caused by the significant magnetic field inhomogeneities and the long EPI readout time. Alternative techniques to 2D ss-DWEPI are currently under investigation, such as DW Half-Fourier single-shot TSE (HASTE/SSFSE) or line scan DWI.[1, 2] DW HASTE imaging is a combination of spin echo diffusion preparation with HASTE acquisition and has been used to obtain diffusion weighted images of non-brain organs such as cervical spinal cord, breast and prostate. However, DW HASTE imaging has inherently poor SNR and blurring artifacts due to the long Echo Train Length (ETL). 2D/3D ss-DWEPI using non-selective and phase encoding (PE) selective double inversion for a reduced-phase FOV (r-FOV) has been developed for high-resolution DTI with reduced FOV and ETL and still allows interleaved multislice imaging.[3, 4] To reduce the FOV and the corresponding ETL in DW HASTE we have implemented a diffusion weighted inner-volume-imaging(DW IVI) HASTE technique. In this technique, a time-efficient interleaved acquisition of multiple slices with a limited FOV was achieved by applying two inversion 180^o pulses with the first non-selective, and the slice-selection gradient of the second applied in the phase-encoding direction.

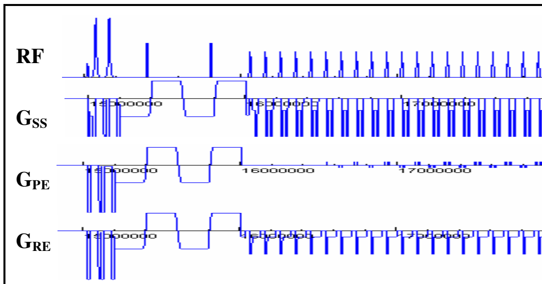

Figure 1 2D DW IVI HASTE pulse sequence

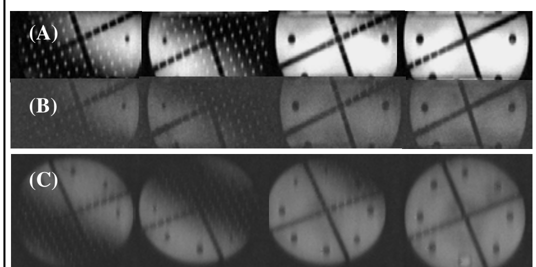

Figure 2 Phantom Images using DW IVI HASTE with b=0 (A) b=500 sec/mm^2 (B) and DW HASTE b=500 sec/mm^2 (C)

METHODS: DW IVI HASTE was implemented using the 2D HASTE sequence. Figure 1 shows the pulse sequence diagram of DW IVI HASTE. A pair of inversion 180^o RF pulses immediately follows the excitation 90° pulse to confine the reduced phase FOV for interleaved multiple slices. These two 180° pulses were similar to those used in double inversion preparation for black blood (one global and one slice selective 180° RF pulses) except that second 180° pulse used a PE selective gradient enabling interleaved multiple-slice acquisition. To reduce eddy current induced distortion the Twice-Refocused Spin-Echo (TRSE) method was used for diffusion sensitization. All MRI studies were performed on a Siemens Trio 3T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) using a 12 channel head coil. To compare the relative spatial resolution between conventional DW HASTE and DW IVI HASTE, phantom images with b=0 and b=500 sec/mm^2 were obtained using both sequences. For DW HASTE: acquisition matrix =256x256, TR/TE = 3000ms/124ms, FOV = 200x200mm, 3mm slice thickness, ETL = 136,, 4 averages and interleaved acquisition of 8 contiguous slices. DW IVI HASTE used the same parameters except: FOV=200x67mm, ETL=48. The optic nerve area of a normal subject was scanned using DW HASTE and DW IVI HASTE with b=0 and b=500 sec/mm^2. The diffusion gradient was applied in the slice direction. Other imaging parameters were the same as for the phantom study except for using a 4mm slice thickness and 8 averages. The total scan time was 4:24 min for the two b-values. After the two b value images were acquired, the ADC map was calculated and displayed. T2w images were also obtained from the same locations using TSE with TE/TR = 64ms/4000ms, FOV=200 mm, slice thickness =4 mm and 512x512 acquisition matrix.

RESULTS: The images shown in Figure 2 were obtained using DW IVI HASTE with b=0 (Fig. 2-A) and b=500 sec/mm^2 (Fig.2-B) from the volume selected by our technique for inner-volume-imaging preparation. The resulting images are of good quality with less blurring than conventional DW HASTE images with b=500 sec/mm^2 (Fig.2-C). Figure 3 shows the T2, and diffusion (b=0, 500 s/mm^2) weighted images of the optic nerve of a healthy volunteer using DW IVI HASTE and the ADC map. Note that the images were acquired using a slice thickness of 4 mm, in which the nerve was mostly contained in a single slice. The optic nerve is clearly shown surrounded on both sides by CSF in the T2w and ADC map.

DISCUSSION: This result demonstrates the applicability of our inner volume imaging preparation scheme to limit the FOV in the phase-encoding direction in a diffusion weighted HASTE sequence. Such a restricted in-plane FOV can be sampled by a shorter ETL resulting in reduced T2 blurring. The DW IVI HASTE pulse sequence was able to acquire accurate DWI measurements of a localized volume without susceptibility or motion-related artifacts because it is a single-shot non-EPI acquisition technique with a short ETL. The new technique should be useful for DWI of the various anatomies such as localized brain structures, cervical spinal cord, optic nerve, heart or other extra-cerebral organs, where conventional 2D ss-DWEPI is limited in usage due to the severity of image distortions.

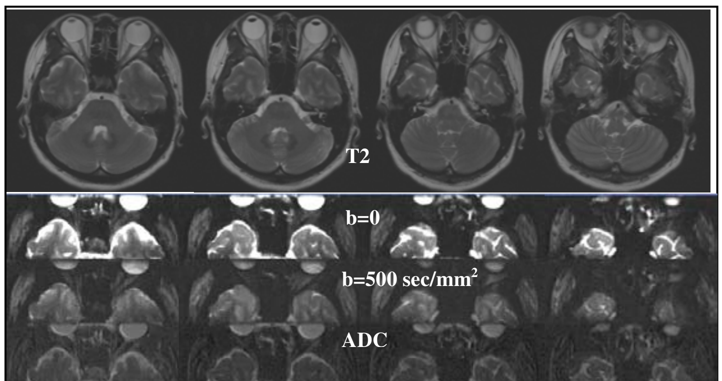

Figure 3 T2w and DWI of optic nerve from a normal volunteer. The ADC map was calculated using b=0, 500 sec/mm^2.

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