Reduced field of view diffusion weighted imaging of the brain at 7T

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Introduction: Due to its high speed and efficiency, single shot EPI is the standard pulse sequence for DWI. However, gradient limitations lead to relatively long echo and readout times, resulting in severe artifacts at high field strength. The long TE causes a loss of SNR, and the long readout time causes geometric distortion and misregistration of fat signal into the brain, as well as T_2 blurring. Undersampling by a combination of parallel imaging and partial Fourier acquisition is applied along the phase encoding dimension in order to shorten the readout and echo times, mitigating these effects (1). Despite these measures, geometric distortion remains severe at 7T in the ventral regions of the brain near the air-filled paranasal sinuses and petrous apices, including the medial temporal lobe, which is a key research target in the early pathogenesis of Alzheimer's disease (2). The purpose of this study was to reduce the artifacts in DWI of the brain at 7T using a combination of OVS (outer volume suppression) -based reduced FOV acquisition (3) with an existing protocol incorporating parallel imaging and partial Fourier methods.

Methods: Five human subjects (four exhibiting early symptoms of dementia) and a high dielectric constant head phantom (doped water) were scanned at 7T using both standard and reduced FOV DTI protocols. Imaging experiments were conducted on a 7T research scanner (GE Healthcare, Waukesha, WI), equipped with an eight-channel phased array head coil positioned within an insert volume transmitter coil (Nova Medical, Wilmington, MA). Prior to the acquisitions, higher order shimming with multichannel B0 mapping was performed using in-house software (4). The standard 7T single shot spin echo EPI DTI protocol includes state of the art methods of axial, full brain coverage at 1.8-mm isotropic spatial resolution (FOV= 23cm, matrix= 128x128, 40 slices), with b=1000 s/mm^2. With R=2 ASSET parallel imaging and 62% fractional k-space phase encoding (40 lines acquired), a minimum TE of 62ms and readout duration of 25ms are achieved. For the reduced FOV acquisition, the number of acquired lines was further reduced by halving the phase FOV (anterior-posterior direction) to a 11.5-cm region covering both temporal lobes (24 lines). The readout duration was thus shortened to 16 ms, while the minimum TE remained unchanged, constrained mainly by limited gradient strength for diffusion encoding. Outer volume suppression was achieved using a pair of custom designed quadratic phase RF pulses (5), which were integrated into the pulse sequence with graphic prescription capability, and placed anteriorly and posteriorly. The pulse (Fig. 1) was designed for low peak power and high bandwidth, for reduced sensitivity to decreased RF coil efficiency and increased B0 variation at 7T. The imaging time for each protocol was 4 min, 12 sec (TR= 9 s, 6 directions, NEX=4). ADC and FA maps were generated from images acquired using both protocols by processing of the diffusion weighted images in FSL.

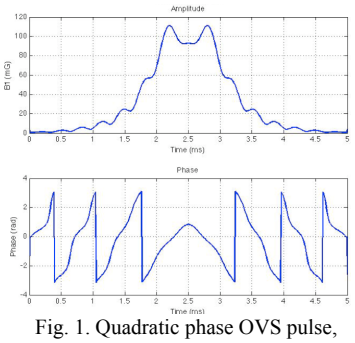

Fig. 1. Quadratic phase OVS pulse, amplitude (top) and phase (bottom)

Fig. 2. Axial DWI data from patient with early symptoms of dementia. Left column- standard acquisition incl. ASSET R=2 (zoomed to match coverage with reduced FOV data). Right column- reduced FOV acquisition. Row 1: b=0 images from slice through temporal lobes. Row 2: DWI images. Row 3: ADC maps. Row 4: FA maps. Bottom left: slice shown on sagittal localizer.

Results: Reduced FOV acquisition dramatically reduced the level of distortions and blurring in diffusion images of the brain, especially in the ventral regions of interest. The diffusion images in Figure 2 demonstrate the artifact reduction in the area of the medial temporal lobe. Performance of the quadratic phase OVS pulses was very good (estimated average suppression > 90%), and was even somewhat better in human subjects as compared to the high dielectric phantom, presumably due to greater B1 variation in the phantom. In addition to a smaller fat shift, the reduced FOV DWI has added fat suppression due to the spatial saturation pulses (beyond the standard chemical saturation pre-pulse already in the sequence).

Discussion: OVS methods were selected over alternative reduced FOV methods for 7T, although those methods were not investigated here. Inner volume excitation using 2D RF pulses (6) is currently unattractive for high field imaging, because of TE prolongation and high SAR, and ZOOM-EPI is limited by wide minimum slice gaps for small targeted regions (7). SNR tradeoffs of our methods due to readout shortening and reduced FOV for parallel encoding require further study.

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