High Resolution Multiple Slice Composite Inner Volume Excitation Echo Planar Diffusion Weighted imaging

H-C. Chang[1,2], T-C. Chao[3], Y-J. Liu[4,5], K-F. Shao[5], C-C. Cheng[2], C-C. Lin[2,6], and H-W. Chung[2,7]
[1]Global Applied Science Laboratory, GE Healthcare, Taipei, Taiwan, [2]Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan, [3]Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, United States, [4]Department of Automatic Control Engineering, Feng Chia University, Taichung, Taiwan, [5]Master's Program in Biomedical Informatics and Biomedical Engineering, Feng Chia University, Taichung, Taiwan, [6]Department of Radiology, China Medical University Hospital, Taichung, Taiwan, [7]Department of Radiology, Tri-Service General Hospital, Taipei, Taiwan

Introduction: The application of diffusion weighted imaging (DWI) has been extensively used in a variety of clinical applications such as dating the evolution of cerebral infarction and detecting the microstructure integrity in human brain with diffusion tensor imaging (DTI)[1-3]. However, DWI has been known for its sensitivity to bulk motion, as a result only single-shot pulse sequences such as echo planar imaging (EPI) is favored to generate robust diffusion contrast. However, the long echo train in EPI acquisition will lead to geometrical distortion due to the inhomogeneous magnetic susceptibility especially in a high field magnet. Many schemes such as parallel imaging and reduced field-of-view (rFOV) approach have been proposed to minimize the distortion artifact by shortening the numbers of readout echoes[4-8]. Inner volume excitation is a rFOV method applying one non-coplanar echo pulse in a spin echo sequence to acquire signal emanating from the region where both 90 and 180 pulses are imposed. As the FOV has been trimmed, fewer echoes will be required to achieve demanded resolution with the inner volume excitation scheme. In this work, a multiple slice inner volume excitation technique was proposed with multiple image segments to acquire a whole brain the EP-DTI dataset. With this composite rFOV method to sample a full FOV image with EPI, susceptibility distortion could be greatly minimized. In addition, instead of using parallel imaging to shorten the echo train in EPI acquisition, the proposed technique is free from related parallel imaging artifact that might provoke potential pseudo-lesion and from noise amplification [8].

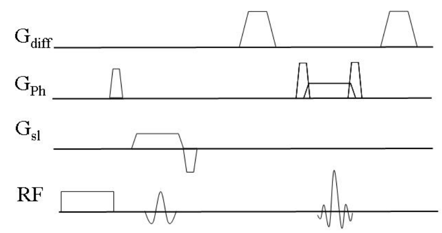

Fig 1. Pulse diagram of pre-IR rFOV excitation scheme. The refocus pulse irradiated along the phase encoding direction

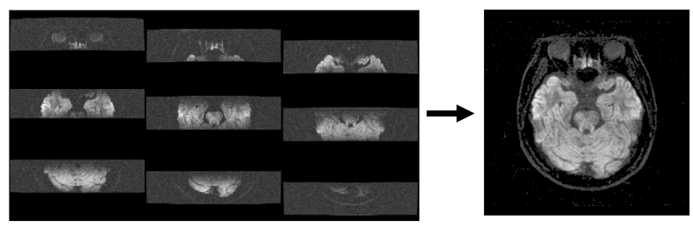

Fig 2 **(a)** **(b)**

Material and Methods: The pulse sequence diagram as shown in Fig 1 was programmed for multi-slice rFOV imaging[7]. A non-selective inversion hard pulse was utilized followed by the excitation. A selective echo pulse for optimal slice selection profile was applied along the phase encoding direction. And EPI acquisition was adopted for sampling the image data. In addition, two crusher gradients clipping the selective echo pulse would minimize the signal from the imperfect refocus pulse and from outside of the FOV. Consequently, the contribution to the echo signal would solely come out from the cross section irradiated by both excitation and echo pulses. For multiple-slice scheme, each excitation sequence is equally separated within one repetition duration (TR). Subsequent to the acquisition of one volume of interest (VOI), the FOV was shifted to acquire the image in the adjacent location. After acquire the entire volume, the images were sorted and located to appropriate location to form a full FOV image. As the 180 echo pulse was applied perpendicular to the acquired slice, the B1 imperfection at the boundary of the excitation profile was noticed around the image. Such effect does no harm to the DTI indices as the integrity indices are calculated from ADC which is a ratio between b0 image and diffusion weighted image. However in order to create visually smooth DWI, overlapping within adjacent volume was introduced for the intensity correction. A root-sum-of-mean-square (RMS) projection was adopted to correct the signal in the overlapping region in a hope to generate a visually normal DWI. Volunteer experiment was performed on a 1.5T GE system. A six-direction DTI sequence was adopted with fourteen continuous slices selected along the sagittal orientation. The acquisition matrix was 160x40 with 4mm slice thickness leading to the resolution of 1.5x1.5x4 mm^3. The echo time was 94 ms with TR set to 5000ms. The b value for DTI was 800 s/mm^2. Nine segments were imaged to cover the entire brain and each segment was averaged by 4 times with concerns in signal to noise ratio.

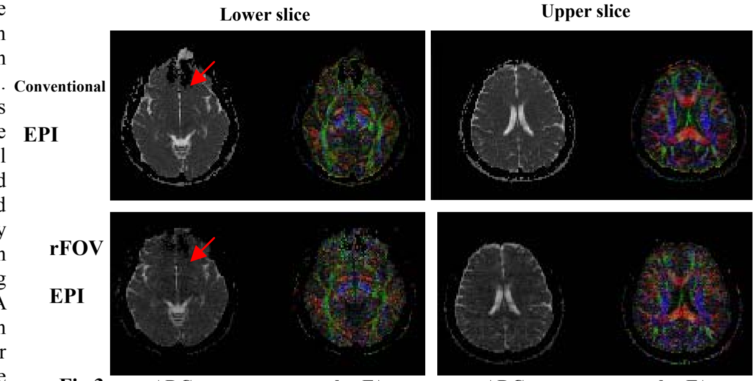

Fig 3

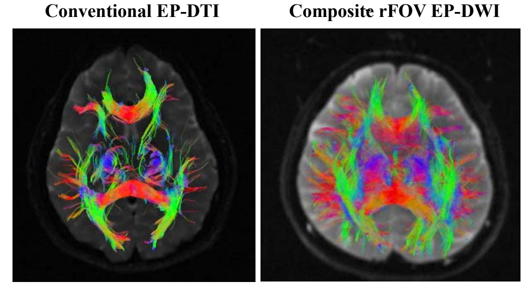

Fig 4

Results and discussion:
Fig 2(a) illustrates the original 9 rFOV image segments of one slice. Unlike conventional EPI image, geometrical distortion was hardly noticed. On the other hand, the inhomogenous intensity profile around the image boundaries was significant. By utilizing the RMS projection from the overlapped voxels, one could sew a distortion less EPI image with smooth intensity profile as shown in Fig 2(b). Fig 3 shows the DTI images from both conventional EP-DTI acquisition and the composite rFOV EP-DTI. In addition to the improvement on the geometric distortion, the susceptibility induced signal loss (indicated by the arrow) was noticed to be less severe in rFOV EP-DTI. Although conventional EP-DTI retains slightly higher signal to noise ratio, the results suggest that the potential SNR loss would be a minor issue of the composite rFOV EP-DTI. Tractographies of the same volunteer from conventional EP-DTI and the composite rFOV EP-DTI were also demonstrated in Fig 4. The number of fiber tracts calculated from conventional method was found to be smaller than those found with the composite rFOV EP-DTI. Moreover, more long fiber tracts were noticed in the tractography result with the inner volume excitation EP-DTI.

In this work, a multiple slice inner volume excitation scheme was introduced with multiple segments acquisition to acquire a full FOV image. With this composite rFOV scheme, the results suggest that the susceptibility effect in EPI will be minimized and a better image quality for EP-DTI could be achieved.

References: [1] Seal, M.L., et al., Schizophr Res, 2008. **101**: p. 106-10 [2] Huang, I.J., et al., Radiology, 2001. **221**: p. 35-42. [3] Garver, D.L., et al, Int J Neuropsychopharmacol, 2008. **11**: p. 49-61. [4] Finsterbusch, J., J Magn Reson Imaging, 2009. **29**: p. 987-93. [5] Wilm, B.J., et al., Magn Reson Med, 2007. **57**: p. 625-30. [6] Jaermann, T., et al., Magn Reson Med, 2004. **51**: p. 230-6. [7] Chao, T.C., et al. ISMRM, 2008. p.1806 [8] Chou, M.C., et al., AJNR, 2007. **28**: p. 1099-101.