High spatial resolution diffusion imaging with inner volume acquisition at 7T

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[Introduction]

High spatial resolution imaging is one of the promised targets for ultra high field MR because of its high SNR. Diffusion weighted imaging (DWI) is sensitive to the diffusion of water molecules so it can provide neuro fiber structure information. It has been expected that high spatial neuro fiber structure information can be acquired at high field strength MRI. At lower field strength such as 1.5T, single shot Echo Planar Imaging (ssEPI) based DWI is a standard acquisition technique for its robustness to patient motion, its short acquisition time, and its high signal to noise ratio (SNR). To acquire high spatial resolution diffusion image with ssEPI, longer echo train is required. At ultra high field (>3T), high magnetic susceptibility results in severe image distortion. To overcome this issue, inner volume single shot echo planar imaging (iv-ssEPI) was used in this study. The iv-ssEPI is insensitive to susceptibility effect because of its shorter echo train length. It may suffer from lower SNR due to limited excitation volume in lower field strength, intrinsic high SNR in 7T system will help to overcome that limitation. The purpose of this study was to investigate the feasibility of 7T iv-ssEPI and to acquire high spatial resolution diffusion weighted image at 7T.

[Materials and Methods]

Inner volume acquisition was implemented to ssEPI based DW imaging sequence. The basic sequence design to excite band shaped inner volume area consists of a selective 90 degree pulse and a selective 180 degree pulse with diffusion gradients on both sides of the refocusing pulse, followed by a standard EPI readout. Inner volume acquisition technique and fractional k-space acquisition were used to minimize EPI readout echo train so as to reduce image distortion and signal loss due to severe susceptibility. The following scan parameters were used for iv-ssEPI based diffusion weighted imaging to acquire brain image. minTE(68.2ms), TR5000ms, rampsampling ON, FOV15cm, Th3.0mm, 256x48, 8NEX, phaseFOV0.4 bvalue 500s/mm^2 (586um pixel size in read direction). For high spatial resolution DWI acquisition with small surface coil, the following scan parameter was used. minTE(87.2ms), TR5000ms, rampsampling ON, FOV8cm, Th3.0mm, 256x64, 8NEX, phaseFOV0.3 bvalue 500s/mm^2 (313um pixel size in read direction). Half Fourier acquisition was used and two echo were oversampled. Chemical shift selective chemical shift selective saturation (CHESS) pulse was used for fat saturation. Three male healthy volunteers (18-22yr) were scanned with the protocol. The study was approved by the institutional review board, and written informed consent was obtained from all volunteers. All volunteer were performed on 7T MRI scanner (SIGNA 7T, GE Healthcare, Waukesha, WI) with head transmit coil and small local receive surface coil with diameter of 5cm (shown in figure 1) was used for high spatial resolution localized imaging. Motion Probing Gradient (MPG) was applied to X, Y and Z direction and three DWI images were acquired. Three diffusion weighted Images were combined and processed to generate diffusion trace weighted image (isotropic diffusion weighted image). Three dimensional anisotropy contrast (3DAC) [1] axonography was also generated to visualize diffusion anisotropy information.

[Results]

Figure.2a represents axial isotropic diffusion weighted image of brain with spatial resolution of 586um acquired at 7T. Image distortion was reduced by using iv-ssEPI acquisition, although small distortion still remains in brain surface area. Figure.2b shows 3DAC axonography of the corresponding slice location. In-plane 586um spatial resolution was achieved with hear transmit/receive coil. Figure.2c shows isotropic diffusion weighted image with 313um spatial resolution by using the small local receive coil. Using small surface coil, we could achieve 300um spatial resolution with sufficient SNR. In both case, signal from outside of selected excited volume effectively suppressed by iv-ssEPI technique.

[Discussion and Conclusion]

Key parameters to reduce image distortion are the echo spacing and echo train length, while key parameter to reduce signal loss is effective echo time of ssEPI acquisition. Effective echo time was also key factor to improve diffusion image quality at 7T, because of shorter T_2 or T_2* relaxation time of brain tissue comparing to lower field strength. Our previous measurement of T_2 relaxation time was about 40ms in white matter and about 45ms in gray matter. These results were comparable with the previous publication [2]. Reducing the number of over-sampling for half Fourier acquisition, effective echo time could be minimized and signal to noise ratio was improved. In this study we have shown that inner volume acquisition enables high spatial resolution diffusion weighted imaging in the sub-millimeter range. Use of small local coil helped to improve SNR to achieve 300um resolution.

[Acknowledgement]

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[Reference]

[1] Neurosci Res. 1995 Jul;22(4):389-98
[2] Quantitative MR I of the Brain, Edited by Paul Tofts, John Wiley & Sons, Ltd.

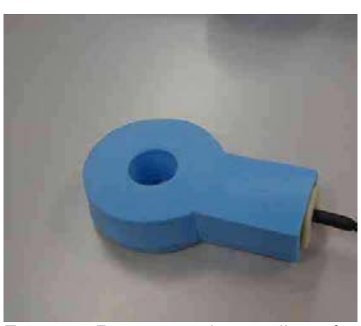

Figure.1 Receive only small surface coil used for high spatial resolution diffusion study.

(a) (b) (c)

Figure.2 (a) isotropic diffusion weighted image of brain acquired at 7T (b) 3DAC axonography of the corresponding slice location (c) high spatial resolution isotropic diffusion weighted image acquired with small surface coil.