HIGH RESOLUTION DISTORTION-FREE DIFFUSION-TENSOR IMAGING OF OPTIC RADIATION USING READOUT-SEGMENTED ECHO-PLANAR IMAGING AND A TWO-DIMENSIONAL NAVIGATOR-BASED REACQUISITION

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Background and Purpose

Diffusion-weighted imaging (DWI) using single-shot echo-planar imaging (SS-EPI) has been used widely for clinical application especially in the acute brain ischemia, but a shortcoming of this method is the presence of bulk susceptibility artifacts, lower signal-to-noise ratio (SNR) and lower spatial resolution. Multi-shot EPI (MS-EPI) also has been applied as an alternative method for SS-EPI method, but the movement among multiple shots still remains unsolved. To improve the image quality of EPI, read-out segmented EPI (RS-EPI) combined with 2D-navigator-based reacquisition was established with high resolution with distortion-free, reduced susceptibility artifact and blurring from T2* signal decay compared to SS-EPI [1, 2]. Distortion-free DWI and diffusion tensor imaging (DTI) has been implemented with this novel method. The optic radiation poses significant challenges to clinicians because of its characteristic anatomic distribution, and more precise anatomical imaging is clinically essential. The optic radiation was difficult to evaluate its entire course with SS-EPI DWI/DTI because of lower spatial resolution. This time, we used readout segmentation of long echo-trains for DTI of the optic radiation. We implemented RS-EPI DTI on 10 volunteers at 3T MR scanner with 32-channel head coil and evaluated the feasibility of clinical application by analyzing color map image and fiber tractography of the optic radiation.

Materials and Methods

RS-EPI DTI was acquired from 4 healthy volunteers using a 3T MR scanner (MAGNETOM Trio, A Tim System, Siemens Healthcare, Erlangen, Germany Version B17, RS-EPI sequence was work in progress, provided by Siemens) with 32-channel head coil. For RS-EPI DTI, the following parameters were used: matrix size=194 x 194; FOV=160mm; voxel size=0.8mm x 0.8mm x 3.0mm; slices=10; readout segments=15 (for full k-space, segments were omitted from reconstruction for partial k-space comparison); TR=5000ms; TE1/TE2=64ms/102ms; echo spacing=0.32ms; scan time=10.47mins. DTI protocol: 1 image at b=0 and 6 directions at b=1000s/mm ^{2}; Diffusion tensor calculation and image analysis were performed by DTIstudio software version 3.0 (H. Jiang, S. Mori; Department of Radiology, Johns Hopkins University). Trace, fractional anisotropy (FA), and color map images were calculated. On the calculated color map image, fiber tractography of the optic radiation was generated using following parameters: start FA > 0.2, stop FA < 0.2, angle between voxels < 70 degrees.

Results

Calculated trace, FA, and color map images were shown on Figures 1-3. RS-EPI DTI showed higher spatial resolution and enabled us to analyze the optic radiation and the adjacent structures such as the tapetum, the superior longitudinal fasciculus, and the cingulum. On color map images, inner structure of the thalamus was also apparent. Fiber tractography of the optic radiation was shown on figure 4. Characteristic curved configuration of the optic radiation and the lateral geniculate body were apparent.

Discussion and Conclusion

This RS-EPI DTI method was robust enough to evaluate the microscopic internal structure of the optic radiation very precisely on the high-resolution images. It was considered difficult to make a precise assessment of the course of the optic radiation by standard SS-EPI DTI because of limited spatial resolution. However, the images gained from this RS-EPI DTI yielded higher spatial resolution without image distortion.

The optic radiation is the greatest concerned region in the whole brain with characteristic anatomical distribution. RS-EPI has relatively longer scan time than SS-EPI, and is more sensitive to patients motion [3]. Even with 3T scanner and 32 channel coil, it's difficult to scan the whole brain in clinically acceptable scan time. To overcome this problem, the effort to make scan time shorter should be attempted in the future.

In conclusion, RS-EPI has much higher spatial resolution compared with SS-EPI and can be a potential to be an alternative to SS-EPI DTI for evaluating the whole brain lesion, such as demyelinating disease, neurodegenerative disease, brain tumors and inflammatory disease.

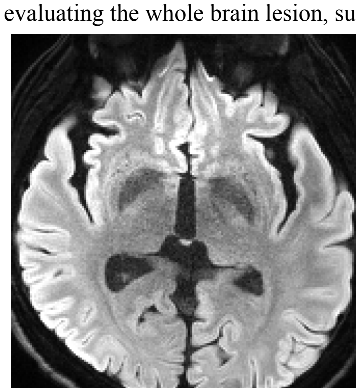

Figure 1

Trace image of RS-EPI DTI shows higher spatial resolution. The optic radiation and adjacent structures were apparent.

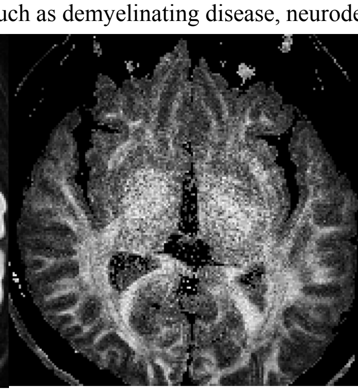

Figure 2

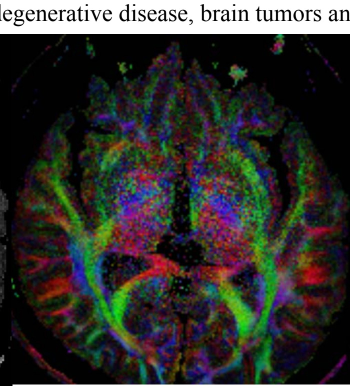

Figure 3

FA map and color map images of RS-EPI DTI shows higher spatial resolution. In addition to the optic radiation, adjacent structures such as the tapetum, the superior longitudinal fasciculus, and the cingulum were apparent. On color map images, inner structure of the thalamus was also apparent.

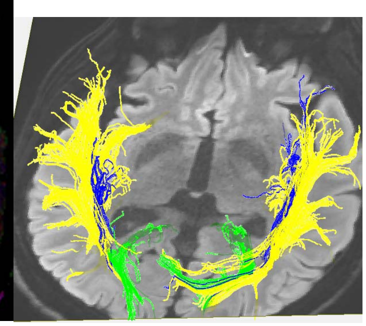

Figure 4

Fiber tractography of RS-EPI DTI shows the optic radiation (yellow), the cingulum (green), and the tapetum (blue).

References

[1] Porter et al. MRM 62:468-75(2009)

[2] Heidemann et al. MRM 64:9-14(2010)

[3] Mukherjee et al. AJNR 29:843-52(2008)