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Introduction: In rodent MRI, a high magnetic field is desirable feature, because it provides a high spatial resolution and a high signal-to-noise (SNR) ratio. This has been used for a high-spatial and high-angular resolution diffusion-weighted imaging (HARDI) *ex-vivo* of the mouse brain [1]. However, for *in-vivo* studies [2] and especially at 16.4T, there are several physical challenges, including magnetic susceptibility, the lengthening of the T_1 relaxation time and the shortening of the T_2 relaxation time. With the HARDI, this results in long experiment time and increased sensitivity to motion [3]. In this study, we optimized the HARDI echo planar imaging (EPI) sequence; incorporated segmentation and a partial Fourier transform (FT) reconstruction in the frequency and phase direction. The 2D HARDI datasets were acquired with 30 or 64 directions with a high b-value in the range of 3000 s/mm^2.

Methods: Four C57BL6 mice underwent a DWI experiments while anaesthetised using 3% isoflurane/oxygen for induction and 1–1.5% for maintenance at a flow rate of 1 L/min. The respiratory rate and temperature were maintained between 60–75 beats per minute and 30^{o}C.

MRI data were acquired on the 16.4 Tesla vertical bore animal system using a micro 2.5 gradient system and 20 mm SAW volume head coil, running Paravision 5.1. A Bruker Stejskal-Tanner pulse-field gradient spin-echo was interfaced with a segmented EPI read-out sequence to acquire the data with the following parameters: TR = 6000 ms, a minimum echo time (TE) = 13.97 ms to accommodate the two identical diffusion gradients with δ/ Δ = 2.4/6.4 ms and a b-value of 3000 s/mm^2. Four dummy scans were employed to reach a steady state net magnetization. 30 or 64 diffusion directions encoding measurements have been acquired within approximately 25 and 55 mins (without respiratory triggering) or 1 and 2h (with the respiratory triggering). Either 1 or 2 excitation averages (NEX) were used to increase the SNR and to reduce the motion artefacts, whilst maintaining a reasonable experimental time frame of 2h.

The MRI data were acquired with 12 or 24 contiguous slices acquired at 0.8 and 0.6 mm thickness with FOV = 1.60×0.96 cm and matrix size = 128×64, resulting in an acquired resolution of 125×150 microns. Partial k-space data were acquired in both the phase- and frequency-encoding directions with the FT acceleration factor =1.35 and FT overscans = 15. The encoding acceleration permits the truncation of the k-space by approximately 30% in the phase direction and, consequently, reduces the experiment time. In the frequency direction, a zero fill factor acceleration of 1.35 was used. No acceleration was used in the read direction, because it did not reduce the TE or the acquisition time. The encoding acceleration allowed the truncation of the echo train length (ETL) and consequently shortens the echo time to avoid acquisition at the late stage of the T_2 relaxation period. The EPI was segmented into 4, 8, and 10 shots to reduce the off-resonance effects and distortion artefacts. Further reduction in the distortion artefacts was achieved using a combination of field-map based shimming for the global head area, followed by a more localized shimming using a voxel derived from PRESS (Point Resolved Spectroscopy) placed in the centre of the brain.

Whole-brain probabilistic fibre-tracking was performed using the program MRtrix [4] with a constrained spherical deconvolution (CSD) [5] to model the multiple fibre orientations (maximum harmonic order, *lmax*=6). Five million tracks were generated, with the following parameters being used, 0.1 mm step-size and maximum angle between steps = 45º. Any track with length < 1 mm was discarded and the termination criteria were to exit the brain or when the FOD amplitude was < 0.01 [1].

Results. The 2D-DW-EPI sequence with four segmentation and NEX=2 demonstrated robustness and reproducibility in acquiring the diffusion measurements with 64 directions at 16.4 Tesla. A higher number of EPI segmentations was not advantageous, because the motion artefact worsened with no clear reduction in the local field inhomogeneity distortion, but this significantly increased the acquisition time. A combination of navigator echo and respiratory triggering was found to be critical for reducing the phase error and consequently, reducing the ghosting from the motion artefact. The image acquired with the 0.6 mm slice thickness produced a better quality image than that with 0.8 mm slices, because of the lower partial volume.

These sequence parameters produced high-quality diffusion tensor parametric images and permitted a high-quality probabilistic tractography using the Constrained Spherical Deconvolution (CSD) reconstruction (Figure1).

Conclusion. The optimized segmented 2D-DWI EPI can produce high-quality diffusion images at 16.4T within a reasonable experimental time. This sequence could be used for assessing animal models that require the longitudinal studies and a non-invasive imaging approach.

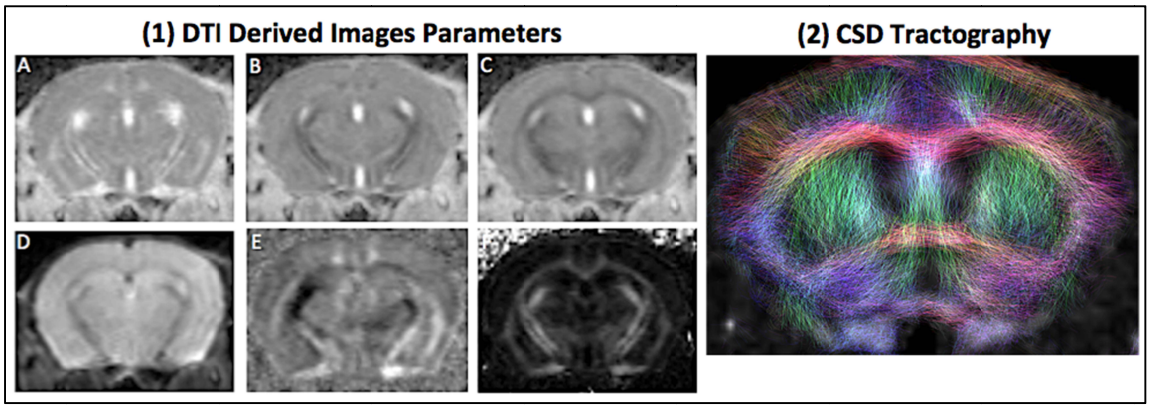

Figure 1. (1) DTI parametric images reconstructed from *in vivo* segmented EPI with 64 directions: (A-C) Eigenvalues (λ_1, λ_2, and λ_3). (D) Trace-weighted image. (E) Tensor component along the X-Z axis. (F) Fractional anisotropy. (2) A whole brain tractography reconstructed using CSD-probabilistic tractography showing the streamlines from a coronal slice at the level of the lateral crossing of the anterior commissure.

References

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