# High temporal resolution diffusion MR Imaging of the mouse spinal cord using Echo Planar Imaging

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**Introduction :**

Diffusion tensor imaging (DTI) provides important information on tissue morphology and structural changes that may occur during pathology. It is widely employed to explore the brain and its application to spinal cord (SC) is more and more frequent. DTI is particularly useful to assess alterations of white matter tracts occurring in multiple or amyotrophic lateral sclerosis, as well as those occurring after SC injury or infarction. Numerous genetically-modified mouse models are now employed to study such diseases, but mouse SC DTI is generally time-consuming: typical acquisition time ranged from 1/2 to several hours [1-3], depending on spatial resolution, number of averages and number of diffusion encoding steps. In cases of rapidly evolving pathology, such as that encountered in SC injury or infarction, high temporal resolution, combined with high spatial resolution would be beneficial to quickly characterize the extension of the pathology or the presence of a second injury.

EPI (Echo Planar Imaging) techniques are largely applied for human SC diffusion imaging; its use on rats has also been reported [4], but it seems that it has not been applied in mouse models so far. Ghosting and susceptibility artifacts, as well as lack of availability of such sequences on high-field system may explain why EPI is not extensively used. Recent improvements in the technology (gradient system, pre-emphasis correction…) have however led to a distinct increase of EPI images quality.

The purpose of this work was thus to demonstrate the possibility of performing high-quality and accurate diffusion measurements of mouse SC using EPI. Our first objective was to validate the method by comparing the apparent diffusion coefficient (ADC) of gray and white matter, derived from EPI measurements, with those obtained using a conventional spin-echo sequence. We then investigated the potentiality of the sequence to perform high-temporal-resolved DTI. The possibility of performing tractography is demonstrated.

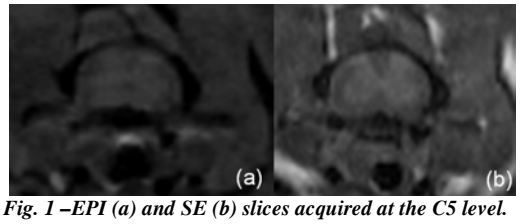


*Fig. 1 –EPI (a) and SE (b) slices acquired at the C5 level.*

**Material and methods:**

C57BL/6J mice were anesthetized with an isoflurane+air mixture and placed in a 3-cm diameter transmitting/receiving birdcage coil. All experiments were performed on a 11.75T vertical Bruker Avance 500 WB system. Sagittal scout images were acquired using a gradient-echo sequence and used to locate the C1 to C7 cervicals. EPI read-out was segmented into four-interleaved shots. Adjustments (trim, shim, B0 compensation) were performed within 5 minutes. Diffusion imaging parameters common to both EPI and conventional Stejskal-Tanner spin echo (SE) sequence were: TR/TE 1500/14.5 ms, $\Delta/\delta$ 6.82/2.3 ms, 3 axial slices (C1/C2, C3, C4/C5), slice thickness 0.75 mm, FOV 17 mm, matrix 128x128, b-values {0, 300, 600} s/mm$^2$, 3 encoding directions (X, Y, Z). Two signal averages (NEX) were acquired for the conventional SE sequence, 10 for the EPI, leading to total acquisition times per direction of 9.5 and 3 minutes, respectively. High-temporally and -spatially resolved EPI DTI was performed with the following parameters: 7 slices, slice thickness 0.75 mm, matrix 160*160, TR 4s, TE 16.86 ms, NEX 20, 6 diffusion encoding directions and 2 b-values. Total acquisition time was equal to 37min20. ADC and DTI were respectively processed using IDL and Brainvisa/Anatomist softwares.

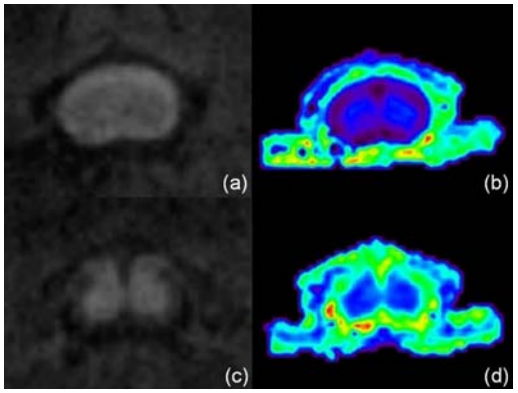


*Fig. 2 – Diffusion-weighted EPI images (left) and ADC maps (right) for ⊥(top) and // (bottom) diffusion encoding.*

**Results :**

Typical images acquired with the SE-EPI and conventional SE sequences are given in figure 1. EPI images were of good quality and distortion and ghosting artifacts greatly limited. Diffusion-weighted images acquired with encodings perpendicular (X) and parallel (Z) to the SC and corresponding ADC maps are shown on figure 2. Figure 3 summarizes the mean ADC values (n=3 mice) measured in 3 different regions of interest (ventral horn, dorsal horn and lateral white matter), with both EPI and SE sequences. No differences were observed between the 2 methods and measurements are in agreement with previously reported values.

Example of fractional anisotropy (FA) map derived from EPI DTI is illustrated on figure 4; partial fiber tracts reconstruction is given as well.

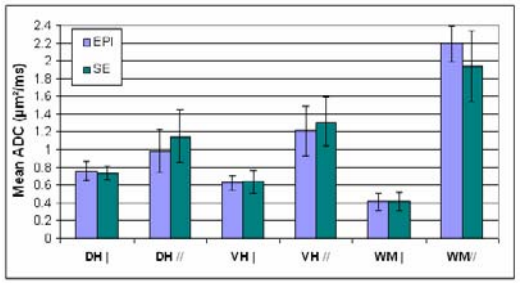


*Fig. 3 – Group average (n=3) and standard deviation of ADC derived from EPI and SE measurements. WM : white matter, DH/VH : dorsal/ventral horns. // : Z-encoding, ⊥: mean of X and Y-encodings.*

**Discussion :**

EPI-derived parameters are similar to those obtained with SE, which is recognized to be a robust technique to measure diffusion values. By using EPI, acquisition time can be decreased by a 3-fold factor without altering the quality of the measurements (as long as proper EPI adjustments have been performed).

The high temporal resolution of EPI may be either exploited to acquire highly-resolved DTI and obtain precise measurements of directionality or diffusivity in a minimal time, or to explore larger volumes. EPI DTI may be especially useful to obtain a rapid and global overview of pathological or therapeutical effects, in cases of rapidly-evolving pathology, or to decrease the time spent under anesthesia (and the associated risk of mortality).

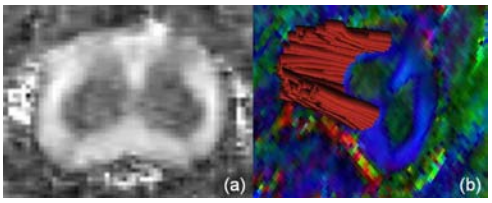


*Fig. 4 – FA (a) map and fiber tracks overlaid on eigen-vector map (b). FA were measured equal to 0.82±0.03 in WM and 0.42±0.04 in GM.*

**References**

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[2] – Bilgen *et al.*, Magn.Reson.Med., 54, 1226 (2005)
[3] – Kim *et al.*, Neurobiol.Diseas., 21, 626 (2006)
[4] – Fenyes *et al.*, Magn.Reson.Imag., 17, 717 (1999)