Short Scan-Time Diffusion Tensor Imaging of the Mouse Thoracic and Lumbar Spinal Cord using Echo Planar Imaging

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Introduction

The first diffusion-weighted images (DWI) depicting *in vivo* mouse thoracic spinal cord (SC) were presented by Bonny *et al*. in 2004 [1]. Since then, many groups have performed thoracic and lumbar DWI studies of normal [2] and diseased mouse models (multiple sclerosis [3, 4], SC injury [4] …). Diffusion-tensor imaging (DTI) has already proved its usefulness to study pathological tissues and white matter alterations, but using standard pulse sequences, DTI is a time-consuming method. Spin-Echo EPI technique applied to mouse imaging has recently been proposed at the cervical levels and a 3 to 4 gain-factor in the acquisition time was demonstrated as compared to conventional SE sequences [5]. However, the application of the SE-EPI technique at lower levels is challenged by higher field heterogeneities and motion amplitude.

In this work, we demonstrated that SE-EPI can be used at the lower thoracic level (T9-T13) as well as at the lumbar level, permitting short DTI scan times. Moreover, by using Outer Volume Suppression (OVS), in-plane resolutions of 86x86 µm² were achieved.

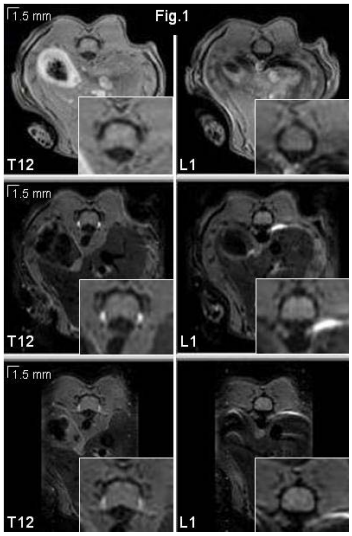
Materials and Methods

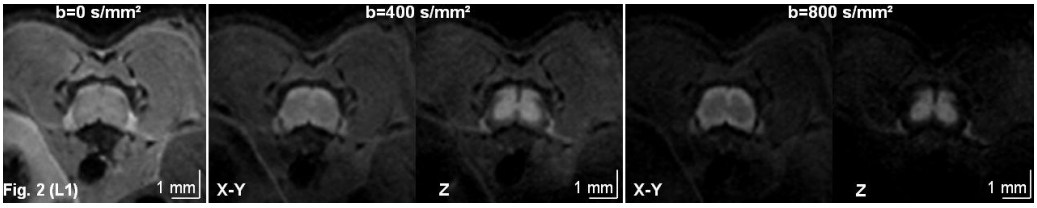
C57BL/6J mice (25-30 g) were anaesthetized with an isoflurane+air mixture and placed in a transmitting/receiving birdcage coil (diameter 2 cm, homogeneous length 3 cm). All experiments were performed on an 11.75T vertical Bruker Avance 500 WB system, in agreement with the guide for care and use of laboratory animals. DWI and DTI MR parameters are summarized in the table below. Acquisitions were synchronized with breath motion (~ 80 respirations/minute).

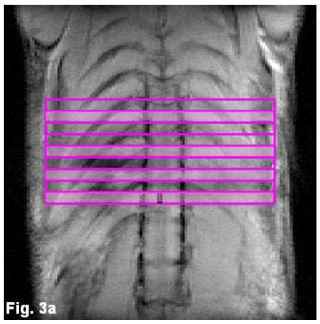
SE-EPI sequence	172x172 µm² in-plane resolution	101x101 µm² in-plane resolution	86x86 µm² in-plane resolution
Shots, TE/TR (ms), OVS	4-shots, 14.25/~750, no OVS	4-shots, 15.43/~750, 2 OVS	8-shots, 14.25/~750, 2 OVS
FOV (mm²), thickness (mm)	22x22, 0.75	15x15, 0.75	12.5x22, 0.75
Acquisition matrix	128x128	148x148	128x256
DWI parameters, directions	b={0, 400, 800} s/mm², x-y and z	b={0, 400, 800} s/mm², x-y and z	b={0, 400, 800} s/mm², x-y and z
DTI parameters	b={0, 700} s/mm², 6 directions	b={0, 400, 800} s/mm², 6 dir.	b={0, 700} s/mm², 6 dir.
Number of averages (NEX)	5	10	10
DWI total acquisition time	0.75 minute/slice/direction	1.5 minutes/slice/direction	3 minutes/slice/direction
DTI total acquisition time	1.75 minutes/slice	6.5 minutes/slice	7 minutes/slice

Results

Figure 1 illustrates the 172x172 µm² (middle) and 86x86 µm² (bottom) EPI images as compared to the gradient echo scout references (top) acquired at the T12 (left column) and L1 (right column) levels. Figure 2 illustrates the high quality of the collected DW images at the lumbar level (L1) whereas figure 3 gives an overview of the DTI metric maps (FA, eigenvectors) that can be derived from acquisitions performed at the T9 to T13 levels.







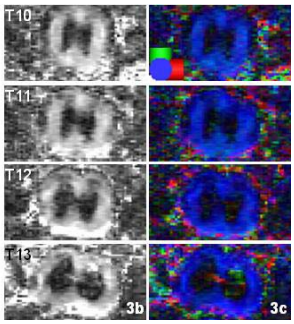


Fig. 1 – (left) T12 level, (right) L1 level. (top) Scout images, (middle) 172x172-µm² EPI images, (bottom) 86x86-µm² EPI images.

Fig. 2 - 86x86-µm² DWI at the (L1) lumbar level. The complete dataset (3 b-values, x-y and z directions) was collected in 6 minutes.

Fig. 3 – 101x101-µm² DTI at the thoracic level. (a) Slices localization, (b) fractional anisotropy and (c) eigen vector maps corresponding to the shaded slices (fig. 3a). The complete dataset (3 b-values, 6 diffusion encoding directions, 9 slices) was collected within 1 hour.

Discussion

In the present study, high-spatially resolved DTI-EPI images were collected on mice at the thoracic and lumbar levels. Respiratory gating and signal averaging have ensured a good stability in the EPI images and DTI metrics were found in agreement with the literature (data not shown).

Thoracic DTI-EPI acquisitions have already been performed on rats [6,7], however, and to our knowledge, it has not been applied so far in mouse models, which present a significant size reduction as compared to rats. Moreover, unlike implantable coils, the birdcage coil used in this study, ensured a completely non invasive and broad investigation of the mouse SC,while providing a good sensitivity.

Conclusion

For physiopathology understanding, as well as for therapy research, DTI is an unavoidable tool that provides unique information regarding the integrity of the white matter and allows non invasive and repeated studies.

The present study demonstrates that *in vivo* high-quality and rapid DTI-EPI micro-imaging of the mouse spinal cord at the thoracic and lumbar levels can be achieved. This technique could permit fast and efficient quantitative characterization of SC lesions, as well as longitudinal follow-up of diseases.

References

[1] Bonny *et al*., Neurobiol. Dis. (2004) ; [2] Bilgen *et al*., Magn. Reson. Med. (2005) [3] Kim *et al*., Neurobiol. Dis. (2006) ; [4] Budde *et al*., Magn. Reson. Med. (2007) ; [5] Callot *et al*., Magn. Reson. Mater. Phy., Magma (2007) ; [6] Fenyes *et al*., Magn. Reson. Med. (1999) ; [7] Madi *et al*., Magn. Reson. Med. (2005).