Multislice Inner Volume MRI for Spinal Cord Diffusion Imaging

B. J. Wilm[1,2], J. Sevensson[1,3], U. Gamper[2], A. Henning[2], P. Boesiger[2], S. Kollias[1]

[1]University Hospital Zurich, Institute of Neuroradiology, Zurich, Switzerland, [2]University and ETH Zurich, Institute of Biomedical Engineering, Zurich, Switzerland, [3]Malmö University Hospital, Department of Radiation Physics, Malmö, Sweden

Introduction

Single-shot spin echo EPI is the most commonly used diffusion weighted imaging (DWI) sequence for the brain, due to its high signal to noise ratio (SNR) and its robustness against bulk motion. However, in the spinal column the application of this technique is limited by susceptibility effects. Especially on high field strength (3 Tesla), the long EPI readout train prohibits the acquisition of high-resolution data. In the brain, parallel imaging (PI) techniques have been successfully used to reduce the readout train length and thereby minimize susceptibility effects. However, in spine imaging the commonly used coil configurations render this approach difficult.

Instead, in this project we present a technique based on a reduced FOV in phase direction. To avoid fold-over effects, a spatially selective signal profile is combined with outer volume suppression (OVS).

Methods

To reduce the size of the signal profile in phase direction, the excitation pulse was tilted an angle α in respect to the imaging plane, similar to [1]. Thus, only the rhomboid compartment of spins that is subject to both the excitation pulse and the refocusing pulse will form a spin echo. To prevent fold-over from the fraction of this compartment that is lying outside the imaging area, outer volume suppression was applied [2]. A schematic graphic of the geometry is displayed in figure 1. The OVS incorporated highly selective quadratic phase pulses [3]; with timings and flip angles optimized for efficient suppression of the surrounding tissues.

Diffusion-weighted (DW) images (b = 750 s/mm^2, 6 DW directions) of healthy cervical and thoracic spinal cord were acquired in axial orientation on a 3T Philips Achieva MR system using a single-shot spin-echo EPI sequence (NSA = 6/12 for b = 0/750, partial-fourier-encoding = 0.6, fold-over-direction = LR). For a rectangular FOV with a matrix size of 144x36, the reduced number of phase encoding lines enabled a reduction in EPI-readout time from 112 ms to 28 ms.

To evaluate the effect of fold-over, images with a tilt angle of 90º towards the imaging plane as done by [4] were acquired for reference.

For the obtained datasets the apparent diffusion coefficient (ADC) and fractional anisotropy (FA) images were calculated.

Results

The obtained DW, ADC and FA images show high signal to noise and contain neither visible susceptibility distortions nor fold-over in the spinal cord. Grey matter (GM) and white matter (WM) could be clearly distinguished on most DW and FA images in the cervical spine.

In the cervical spine, mean FA in the GM/ WM was 0.3±0.1/0.7±0.1, with a mean ADC in both WM and GM of 1.1±0.1·10^{-3} mm²/s (n=3).

In the thoracic spine GM/WM differentiation was not possible due to the smaller dimension of the spinal cord. Mean FA in the thoracic spine was 0.7±0.1 mm²/s mean ADC was 1.0±0.05 10^{-3}. mm²/s (n=2). Figure 2 and 3 show transversal FA and mean DW images of the cervical and thoracic spinal cord which were acquired using a tilt angle of α = 25 º in a multislice setup.

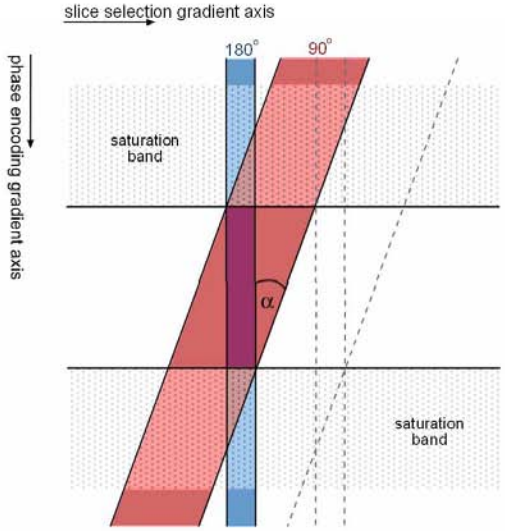

Figure 1: schematic grafic of slice selection geomerty

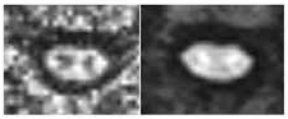

Figure 2: transversal FA and mean DW image of the cervical spinal cord
Voxel size: 1.1 x 1.1 x 5 mm³

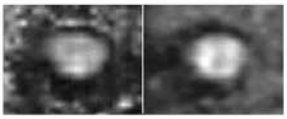

Figure 3: transversal FA and mean DW image of the thoracic spinal cord
Voxel size: 0.8. x 0.8 x 5 mm³

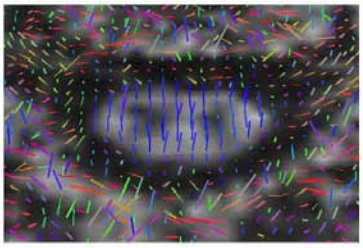

Figure 4: tiled view on FA image of the cervical spinal cord overlayed with main eigenvectors colorcoded and weighted by FA values.

Conclusion

The feasibility of this novel inner volume imaging approach was shown. The reduction of the FOV in phase direction is achieved by a combination of a rhomboid signal profile and OVS. The reduction in readout time enabled high resolution single-shot EPI imaging of the spinal cord. The virtually artefact-free images, and the short imaging time makes this method promising for clinical diffusion imaging of all parts of the spinal cord.

Reference

1.Wheeler-Kingshott [2005] et al. Magnetic Resonance in Medicine 47:24–31
2. Wilm et al. [2005], ESMRMB p 222
3. Schulte RF et al. [2004] JMR 166(1):111-122.
4. Feinberg et. al [1985] Radiology; 156:743-747