Toward a better description of the gray matter spinal cord by using highly resolved diffusion-weighted and morphologic T2*-weighted MRI.

V. Callot[1], G. Duhamel[1], A. Vignaud[2], and P. J. Cozzone[1]

[1]UMR 6612 CNRS, Université de la Méditerranée, Centre de Résonance Magnétique Biologique et Médicale (CRMBM), Marseille, France, [2]Siemens Healthcare, Saint-Denis, France

Introduction

Damages of the spinal cord (SC) may be caused by a wide range of pathologies and can result in important functional disability. The detection of SC abnormalities is nowadays based on MRI with conventional anatomic spin-echo or gradient-echo sequences. Diffusion MRI is additionally used to assess the structural integrity of the spinal cord [1], however the resolution usually achieved for diffusion-weighted images (generally in the range of 1.5x1.5 mm² [2-4]) precludes differentiating with accuracy white matter and gray matter.

In this preliminary work, high-contrasted and high-spatially resolved multi-echo gradient-echo and multislice diffusion-weighted echo planar imaging (respectively 0.5x0.5 mm² and 0.9x0.9 mm² in-plane resolution) were performed for accurate anatomical delineation of the spinal cord GM and WM structures.

Materials and Methods

Experiments were performed on a 1.5T MR system (Avanto, Siemens, Erlangen), using a 12-channel head coil and a 4-channel neck coil array. The MR parameters of the multi echo gradient echo (MGE) sequence were: 5 echoes, TR/TE 500/27 ms, in-plane resolution 0.5x0.5 mm², slice thickness 3mm. Images were acquired perpendicular to the spinal cord axis. The same slice orientation was used for diffusion weighted imaging. Acquisitions were performed with single shot EPI after an inversion recovery (TI=150 ms for nulling the fat signal) with the following parameters : iPAT 2, TR/TE 7600/77, in-plane resolution 0.9x0.9 mm², slice thickness 6mm, 10 slices, b=600 s/mm^{-2}, diffusion encoding along the slice direction and total diffusion acq. time 3 minutes.

Results

The typical butterfly shape of spinal cord gray matter (anterior and posterior horns) was extremely well delineated using both multi gradient echo and diffusion-weighted images as illustrated on figure 1. With diffusion gradient encoding along the slice direction, white matter signal rapidly decreased (ADC_{WM} ~1.6.10^{-3} mm²/s [5]), strongly enhancing the contrast of gray matter structures in transversal plane. Spinal roots and spinal canal were additionally recognizable. 3D-reconstruction of the diffusion weighted images is presented on figure 2 along with superimposition of DWI and MGE images (axial slice).

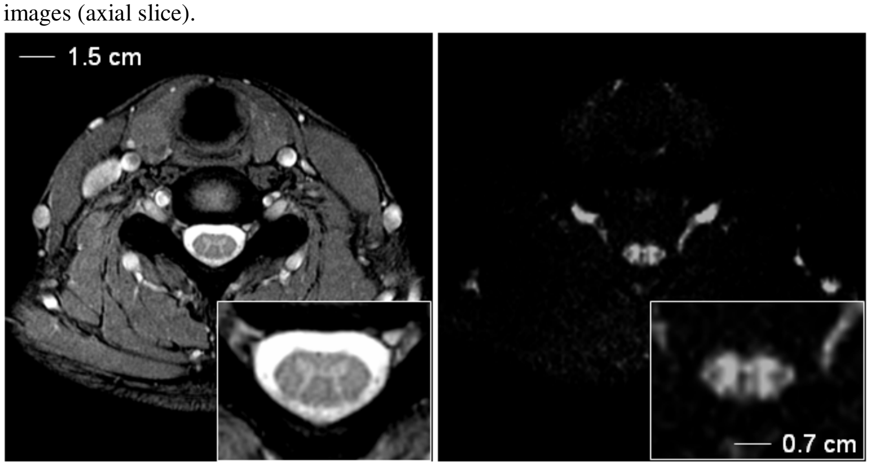

Fig.1 – Transversal multi echo gradient echo (left) and diffusion-weighted (right) images and zoom x2 images, at C4 level. Diffusion-encoding is performed along the slice direction.

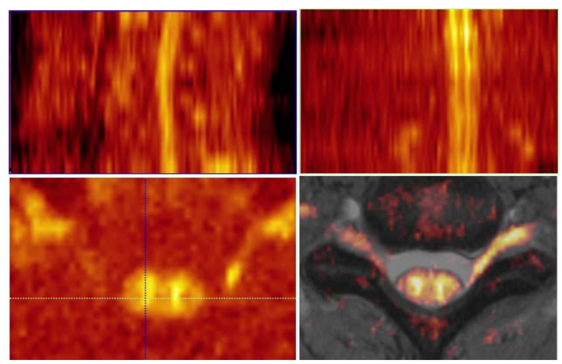

Fig.2 – Color-coded diffusion-weighted images: (top left) sagittal cross-section at the level of the right gray matter (vertical blue line on transverse image), (top right) coronal cross-section at the level of the anterior horns (horizontal green line), (bottom left) transverse image at the level of C5, (bottom right) superimposition with gradient echo image.

Discussion

Assessment of a reliable characterization of the gray matter may be of importance in the pathologic description of diseases, such as spinal cord infarction or compression. Resulting lesions, which are mainly located in the gray matter and which may cause important motor disability, may be difficult to diagnose. The combination of both high-resolved T_2*-weighted morphologic and diffusion-weighted structural images may greatly help by providing complementary information (hemorrhage, edema, ischemic lesion ..). Moreover, the superimposition of both series may help to emphasize and control mismatch indicative of a pathology. Both modalities are currently performed with different slice thickness, which constitutes a bias to a perfect match; if possible the slice slab should be identical so as to minimize partial volume effects. On the other hand, the higher resolved gradient echo images may serve as a mask to automatically and accurately analyze the DWI images, which may help to assess the gray matter integrity.

Conclusion

The ability of generating high image contrast is critical to differentiate white and gray matter in SC. The combination of both high-resolved morphologic and structural MR techniques used in this preliminary descriptive work is a first step on the development of a method able to provide a more complete picture of destructive aspects of the gray matter spinal cord. Images should help in the early and regional detection of gray matter SC lesion and injury. Further work is required to establish the clinical relevance and outcomes. Further developments are considered to increase spatial resolution of the DW images. Application of these techniques to patients suffering from spinal cord injury and spinal cord trauma will be performed.

References

[1] Clark, NMR in Biomed (2002), [2] Ellingson, AJNR (2008), [3] Agosta, Brain (2007), [4] Ciccarelli, Brain (2007), [5] Rossi, JMRI (2008).