Diffusion anisotropy MRI for quantitative assessment of recovery in injured rat spinal cord


Introduction

Spinal cord (SC) injury (SCI) and its devastating outcome is the subject of intensive work aimed at minimizing the damage and inducing some recovery. A major problem in both research and clinic, is the difficulty to assess the state of the injured SC. Diffusion weighted MRI (DMRI) is a potential candidate in aiding in this problem. Changes in the apparent diffusion coefficients (ADCs) following SCI were already characterized, and reasons for these changes were raised (1). SC DMRI detection measurements were also performed in humans, in-vivo (2). We suggest a modified analysis of the diffusion anisotropy (AI), which eliminates interfering noise and which can yield simple morphological parameters, that will enable quantification of SCI. These parameters enabled us documentation of processes such as the related white matter (WM) secondary degeneration, as well as induced rescue of cells.

Materials and Methods

Inbred female adult Lewis rats (24 rats, 10–12 weeks old, 180–220 g) were anaesthetised and injured at the level of T7–T8 using a controlled weight-drop. Within an hour of the injury, some of the rats were injected intraperitoneally with 107 cells specific to the central nervous system self anitgen myelin basic protein (Tmbp) for neuroprotection (3). Control rats were injected with Phosphate buffered saline. Locomotion was assessed at 15 days and 60 days after the injury. X-axis corresponds to the slice number, slices 1–9 correspond to top to bottom SC slices, respectively. Color code was scaled on the range [-0.4,1].

Discussion

Towards a modified analysis of the diffusion anisotropy MRI (AI), which eliminates interfering noise and which can yield simple morphological parameters, that will enable quantification of SCI. These parameters enabled us documentation of processes such as the related white matter (WM) secondary degeneration, as well as induced rescue of cells. Quantification of the lateral degeneration is expressed by the significant differences in the averaged AI and mean-AI values for the 9 slices (averaged over each group) are depicted in Fig. 2. The curves reveal the decline in degenerative processes with distance from the site of injury. In addition they reflect the induced rescue of anisotropic tissue by the difference between the two groups curves of both parameters. The said processes are reflected in the AI-maps as well.

Fig. 1 depicts two representative AI maps (5 slices out of 9). The maps indicate that near the site of injury, the anisotropic area is smaller. In both size and shape of the AI area, the averaged mean-AI and SAI values for the 9 slices (averaged over each group) are depicted in Fig. 2. Towards the SOL both parameters gradually decline. In both graphs there is a significant difference between the treatment and control rats. The quantification of the longitudinal degeneration is expressed by the gradual decrease of the averaged AI and SAI as a function of the slice location (Fig. 3). The curves reveal the difference in degenerative processes with distance from the site of injury. In addition they reflect the induced rescue of anisotropic tissue by the difference between the two groups curves of both parameters. The quantification of the longitudinal degeneration is expressed by the gradual decrease of the averaged AI and SAI as a function of the slice location (Fig. 3). The curves reveal the difference in degenerative processes with distance from the site of injury. In addition they reflect the induced rescue of anisotropic tissue by the difference between the two groups curves of both parameters. The said processes are reflected in the AI-maps as well.

This study demonstrates the potential of DMRI AI-analysis in quantifying SCI in the context of SC degeneration and recovery, and outlines a way to obtain it. The SAI being a sum, incorporates WM changes, which reduce the AI, and the net decrease in WM cross-section area. The analysis requires merely two orthogonal MRI scans and includes noise rejection, suggesting future use for in-vivo experiments.

Fig. 1: Representative AI maps of 2 injured cords: Tmbp treated (top), and control (bottom). 3rd slice is located at the assumed SOL. Left to right correspond to top to bottom SC slices, respectively. Color code was scaled on the range [-0.4,1].

Fig. 2: Longitudinal dependence of the 2 parameters along the site of injury. X-axis corresponds to the slice number, slices 1–9 correspond to top to bottom, respectively. The averaged mean-AI value (left), averaged SAI (right). Dashed line-treated group, solid line-control group.

Fig. 3: Comparison of the SAI value at the SOL. Bar plot depicting the significance difference between the two groups (left), Correlation of the locomotion score (0–21 values scale), and the SAI value at the SOL (right). Filled squares - treated group, empty squares - control group.