Diffusion Tensor and Magnetization Transfer Measurements of Spinal Cord Injury

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Introduction Early and accurate assessments of the extent of an individual's spinal cord injury (SCI) is crucial in defining the appropriate acute therapeutic interventions as well as predicting long-term outcome. In addition, there is a great need for non-invasive and objective methods of quantifying the extent of neural changes following intervention or therapy. Using a well-characterized rodent model with a moderate severity contusion injury we have followed animals to 42 days post injury using diffusion tensor MR imaging. The animal's gait was assessed with 2-D kinematic analysis and with Basso, Beattie, Bresnahan (BBB) locomotor rating scale scoring.

Methods Female, Long-Evans rats weighing between 200-225 gm received a moderate severity spinal cord injury at T10 using an IH impactor (PSI). The injury was computer controlled to achieve an impact force of 150 Kdynes. After injury, an inductively coupled RF coil (27 mm X 14 mm X 5 mm) with passive decoupling was implanted around the spinal cord. The animals were imaged on a 1.5 T Siemens Vision system on days 2, 7, 14, 28 and 42 after injury (dpi). For imaging the animals were positioned supine with the implanted coil directly above a 4 cm receive-only coil. Diffusion sensitized spin echo images were acquired in the three directions. The diffusion images had a resolution of 200 X 200 X 2000 μm^3 and a maximum sensitivity of $b=222\ s/mm^2$. From the images, the apparent diffusion coefficient (ADC) was calculated and an anisotropy index was derived as ID = (DT/DL), where DT = apparent diffusion coefficient measured transverse to the spinal cord and DL = apparent diffusion coefficient along the spinal cord. Magnetization transfer images (+/- MT RF pulse) were acquired with the same resolution and in the same planes as the diffusion measurements. From images acquired with and without an off-resonant RF pulse the MT ratio was calculated as, MTR=100%[1-S(+rf)/S(-rf)].

The animal's gait was assessed using both weekly BBB scoring during locomotion in an open field and 2-D kinematic analysis performed on video images of the foot prints of the animals as they walked across a translucent bridge. Measurements of hind limb rotation, front-back limb coordination, step frequency, stride length and body velocity were assessed.

Separate groups of animals were euthanized at 14 and 42 dpi. The animals were perfused with para-formaldehyde and the cords removed and subsequently cryosectioned for histological analyses.

Results After injury the trace of the diffusion coefficient was larger at the site of injury than either rostral or caudal, particularly in the gray matter where the increase was due predominantly to the increase in DT. The AI at the site of injury for both white matter and gray matter started at 0.4 on day 2 post injury (pi) and increase with time to approximately 1.0 on day 14 pi. Beyond day 14 pi the AI gradually diminished. The average AI for sham treated rats after one week of recovery was 0.24. MT measurements for the entire cord at the site of injury also increased to day 14 pi and then decreased toward 0%.

At 42 dpi the SCI animals obtained a BBB score of 12.0±1.0 with frequent to consistent plantar placement but lacking consistent coordination. The angle of hind foot abduction was consistently larger in injured than in sham treated animals. The animal's body velocity slowed with injury and the reduction came primarily from a decrease in the animal's stride length.

Discussion No animals were lost due to infection from the implantation of the coil. In addition, the 2-D kinematic studies or the BB scores did not reveal any adverse effects on the animals' gait due to the implantation of the coil. The diffusion measurements appear to show the greatest sensitivity in identifying the site of injury and changes occurring post injury.

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