# Imaging corticospinal tract connectivity in injured rat spinal cord using manganese-enhanced MRI

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## Introduction

Corticospinal tract (CST) connects the cerebral cortex to the motor neurons in the spinal cord (SC) and is of particular interest in experimental spinal cord injury (SCI) research [1]. Manganese-enhanced MRI (MEI) offers a novel neuroimaging tool to anterogradely trace this long descending pathway in live animals [1]. This paper expands this capability further and tests the utility of the MEI to image axonal fiber connectivity in CST of injured SC.

## Materials and Methods

All MRI scans were performed on a 9.4 T INOVA Varian system (Varian Inc., Palo Alto, CA) with 31 cm horizontal bore magnet. The spinal cords of Sprague Dawley rats were injured by contusion (incomplete) at the thoracic T4 level. Manganese (Mn) was injected intracortically at two weeks post injury, and the injection site at the motor cortex was stimulated electrically to label the CST [1]. Next day, the injured SC was imaged using anatomical, MEI and diffusion tensor imaging (DTI) modalities. Anatomical data were obtained $T_R/T_E$ = 2500/12 ms, field-of-view (FOV) =10 X 10 $mm^2$, image matrix = 128 X 128, slice thickness = 2 mm and NEX = 2. MEI data were obtained using inversion-recovery sequence with the same parameters, except $T_R/T_E/T_I$ = 2000/15/550 ms and NEX = 4. The DTI data were obtained using diffusion sensitizing gradients along the directions (110,101,011,-110,-101,0-11). Diffusion weighting was achieved using gradient strength = 80 mT/m, width ($\delta$) = 6.5 ms and separation ($\Delta$) = 11 ms to produce b-value of b = 342 $s/mm^2$ while TR/TE = 2500/26 ms and other parameters as in anatomical imaging.

## Results and Discussion

Figure 1 shows anatomical, MEI and DTI data obtained from two normal sections rostral and caudal to the injury, and from the injury epicenter. Anatomic images depict the injured tissue morphology in greater detail at the epicenter as well as the normal cord at sections rostral and caudal to the injury site. In the rostral section, MEI depicts signal enhancement confined spatially to the ventral-most part of the dorsal funiculus between the dorsal horns of the gray matter. This enhanced region overlaps exactly with the expected anatomical location of the CST in rat SC. Signal enhancement is also seen at the expected CST location caudal to the injury. Since Mn is transported by neuronal axons, the Mn-labeling seen below the injury suggests the possibility of some caudal fibers that are still connected to the rostral sections. Careful examination of the image from the injury epicenter reveals a thin strip of signal enhancement, which is situated right posterior to the central canal between the dorsal roots. With the help of DTI, Mn-labeled tissue at the epicenter can be seen as being part of the CST.

In conclusion, combining these results collectively demonstrated the feasibility of imaging fiber connectivity in experimentally injured SC using MEI. This approach may play important role in future investigations aimed at understanding the neuroplasticity in experimental SCI research.

## References

[1] Bilgen, M et al. Magn. Reson. Imag. 23:829-32, 2005.
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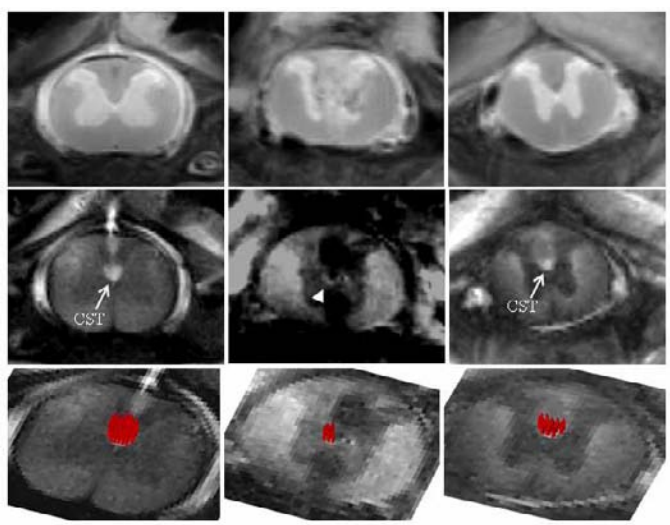


**Figure 1.** Top row: axial anatomical images showing injured spinal cord at there locations rostral to injury (left), injury epicenter (middle) and caudal to injury (right). Middle row: MEIs showing Mn-enhanced CST at the same locations. The partial signal enhancement, depicted by the arrowhead, is likely to represent a portion of the injured CST that is still populated with intact fibers. By continuously projecting through the injury site, these intact fibers transport Mn from rostral to caudal sections. Bottom row: cigar-shaped ellipsoidal representation of the principal eigenvectors estimated from the DTI measurements. Vector directions are all aligned along the cord in all the three images. The direction of the alignment is consistent with the anatomical orientation of the descending neuronal fibers in the CST. The densities of the vectors are also well associated with the sizes of the Mn-enhancement in each slice.