

Variations of intensity patterns of manganese-labeled corticospinal tract with spinal levels

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Introduction

Corticospinal tract (CST) connects cerebral cortex to the motor neurons in 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 [2] and detect axonal fiber connectivity in injured SC [3]. Anatomically, the transverse size and shape of the overall SC as well as its gray matter white matter MR intensity pattern varies in cervical, thoracic, lumbar and sacral regions of the vertebral body. The same is true for the CST. That is the cross sectional size and shape of the CST also shows spatial dependence as it descends through these regions. The goal of this paper is to establish a baseline on the intensity patterns of the manganese (Mn) labeled CST in different levels of SC in normal rat. This normative data would allow detecting any changes occurring in the normal pattern of CST due to dysfunctional axonal fibers as a result of SCI or neuropathological alterations.

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. Sprague Dawley rats were subjected to an intracortical Mn injection (DOSE) bilaterally at the motor cortex. Immediately following this procedure, the injection site was stimulated electrically to label the CST [1]. Next day, the injured SC was excised and imaged using high resolution anatomical MRI and MEI modalities. Anatomical data were obtained using $T_R/T_E = 2500/12$ ms, field-of-view (FOV) = 10×10 mm², image matrix = 128×128 , 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.

Results and Discussion

Figure 1 shows axial Mn-enhanced and anatomical images side-by-side, both acquired from the same level of the SC. The anatomical images were provided as a reference and clearly depict the cross-sectional variations of SC in greater detail at the cervical and thoracic regions. The CST in rat is spatially located at the ventral-most part of the dorsal funiculus between the dorsal horns of the gray matter. According to the patterns of intensity enhancements in the figure, the CST appears covering the whole frontal aspect of the funiculus near the central canal at the cervical level. The pattern is more circularly shape at the upper thoracic level, and divides into two ellipsoidal shapes like a wing of a fly, each lying against the gray matter at the lower thoracic regions. These patterns are consistent with the previous observations made on the histological specimens of SC whose CSTs were labeled with traditional neurotracers [4].

Figure 2 shows data from an injured SC. As in normal cord, the CST is seen as two thin strips of enhancement confined next to the gray matter at normal sections above and below 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 strip of signal enhancement, which is situated right posterior to the central canal between the dorsal roots. This enhancement may represent these active fibers [3].

Conclusions

Combining these results collectively demonstrated the feasibility of imaging CST using MEI. This allowed defining the patterns of Mn-labeled CST at different levels of the SC. The results also showed fiber connectivity in injured SC. This approach may play important role in future investigations aimed at understanding the neuroplasticity in experimental SCI research.

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References

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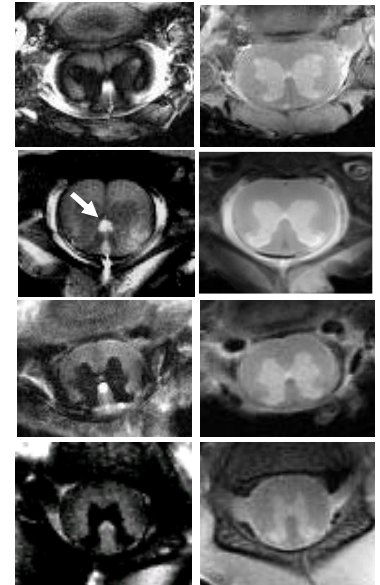


Figure 1. Axial Mn-enhanced (arrow, left column) and anatomical (right) images viewed at cervical (top row) and thoracic (the remaining three rows) levels.

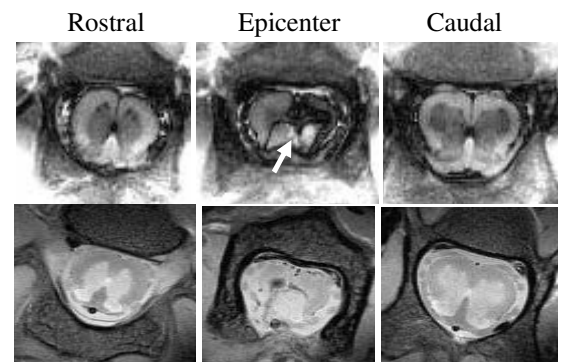


Figure 1. Mn-enhanced (top row) and anatomical (bottom row) images at the thoracic-lumbar levels of an injured SC. Mn-labeled CST below the injury indicate the presence of intact fibers (arrow) at the epicenter transporting Mn from rostral to caudal sections.