Fiber Tracking of Cervical Spinal Cord and Nerves

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Introduction

Structural disorders affecting the spinal cord and nerve roots carry great social cost. Imaging studies are central to their diagnosis and management. Methodology to directly assess nerve integrity or disruption could be of great value in improving diagnosis. Only few studies have investigated diffusion tensor imaging (DTI) and fiber tracking in human spine [1-4]. While these studies present fiber tracking results of spinal cord, none of these present fiber tracking of spinal nerves. Unavailability of high signal-to-noise (SNR) surface coils, subject motion due to swallowing and breathing, as well as tissue–air and tissue–bone interfaces, which cause susceptibility-induced artifacts increase the difficulty of obtaining such data. In the current study we sought to investigate the feasibility of fiber tracking of human spinal cord and spinal nerves in-vivo with diffusion tensor imaging.

Methods

Imaging was done on a 3 T MR scanner (Siemens TIM Trio, Siemens Medical Solutions, Erlangen, Germany) using an in-house designed and constructed 8-channel phased array coil originally targeted for carotid artery imaging [5]. The coil mounted on a frame with head-holder consists of two curved paddles, each with four overlapped 48 mm diameter surface coil elements. The bilateral coil pair was positioned below the jaw to cover the left and right sides of the subject's neck. EPI diffusion tensor imaging scans were performed in axial oblique orientation on one subject with the following imaging parameters: TR = 6.1 s, TE = 89 ms, 49 slices, matrix size 96x96, 144 mm FoV, 1.5x1.5x1.85 mm^3 voxel size, bandwidth 1370 Hz/px, 2-fold acceleration using GRAPPA [6], 10 non-diffusion-weighted volumes, 120 diffusion-weighted volumes with a b-value of 450 s/mm^2, resulting in a scan time of ~13 min.

Fiber tracking and visualization were performed using custom-made programs (see http://www.trackvis.org/) written in C++ using Qt and VTK. The fiber tracking algorithm is based on the Fiber Assignment by Continuous Tracking (FACT) algorithm [7]. Fibers were selected if they passed through the intersection of two perpendicular 40 mm thick slabs in sagittal and coronal orientation. Shown fibers were additionally limited to a length of more than 30 mm to exclude short and potentially erroneous fibers.

Results and Conclusion

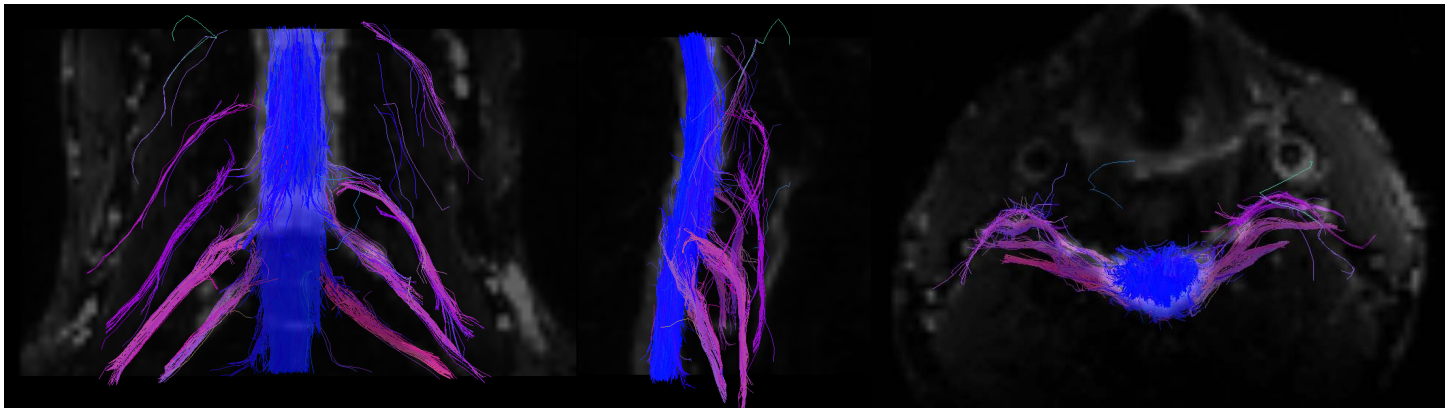

***Figure 1**: View of spinal cord and spinal nerves fiber tracts from posterior (left), right (middle), and superior (right).*

Taking advantage of the close proximity to the target tissue, the use of the 8-channel phased array coil resulted in a strong increase in SNR compared to the large FoV manufacturer supplied 2-element neck coil. Selection of the neck as target volume allowed the use of local surface coils and a small FoV without causing image wrap. The spinal cord as well as the spinal nerves that pass between each disk can be visualized well using fiber tracking (Figure 1). The section of the nerve proximal to the spinal cord is less well defined for most nerves, likely caused by thinner diameter as well as larger curvature in this area. Coil sensitivity drop-off towards the superior and posterior part of the scan volume limits the ability to perform fiber tracking in these areas.

Extension of this method to the thoracic and caudal spine will soon be feasible as optimized RF coils become available. It would also depend on either the local coil sensitivity profile or a method that employs small FoV scans to prevent image wrap. This study shows that diffusion tractography with parallel acquisition has unique potential for imaging the spinal cord and spinal roots, and that the basic technical barriers to diffusion tractography in the peripheral nervous system can be overcome by using existing technologies. We conclude that diffusion tensor imaging and fiber tracking of human spinal cord and spinal nerves in-vivo can be accomplished within the time constraints of a clinical study. Higher spatial resolution, better SNR or non-tensor based approaches may be required to allow successful fiber tracking in the area between spinal cord and nerves.

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References

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