Examination of Cardiac-Related Motion in the Lower Thoracic and Lumbar Spinal Cord

D. Yau[1,2], C. R. Figley[1], C. Nahanni[1], and P. W. Stroman[1,3]

[1]Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada, [2]Faculty of Health Sciences, Queen's University, Kingston, Ontario, Canada, [3]Departments of Diagnostic Radiology and Physics, Queen's University, Kingston, Ontario, Canada

Introduction:

Functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) possess significant potential as clinical tools to investigate spinal cord injury, and assess novel therapeutic strategies. However, spinal cord motion is the dominant physiological source of error interfering with the reliability of these imaging modalities. Moreover, the physiological parameters influencing spinal cord motion have yet to be fully characterized, thereby hindering methods to correct for such motion. The cardiac cycle is known to induce a predictable oscillatory pattern of motion in the cervical and upper thoracic spinal cord, which is maximal in the anterior-posterior direction.[1] Moreover, this motion has been shown to reduce the sensitivity and reliability of spinal fMRI and DTI data.[2] The present study extends this research to the lumbar region, completing characterization of motion in the entire spinal cord.

Methods:

Research subjects: Data was obtained from healthy subjects (N=8; four female, four male) with no history of spinal injury. They ranged in age, weight and height from 21 to 26 years (mean 24 $\pm$ 1), 54 to 91 kg (mean 67 $\pm$ 14), and 1.55 to 1.83 m (mean 1.71 $\pm$ 0.11), respectively.

Study design: All experiments were performed in a 3T Siemens Magnetom Trio. Subjects were positioned supine, and peripheral pulses for each subject were monitored throughout the experiment. Following acquisition of three-plan localizer images, a single 3 mm-thick, mid-sagittal slice with FOV 200 x 200 mm^2 was positioned with its inferior margin at the caudal end of the lumbar region. Data was acquired using a cardiac-gated, turbo-FLASH (fast low-angle shot) cinematic imaging pulse sequence. The sequence was retrospectively gated over the course of many peripheral pulses, resulting in images obtained at 24 phases throughout the cardiac cycle. Following this sequence, the mid-sagittal slice was repositioned rostrally, with the inferior margin overlapping one vertebral level with its initial position. Due to differences in spinal curvature and vertebral body height, the superior-inferior span was variable across individuals.

Analysis: For each mid-sagittal slice, a seed point was manually selected at the spinal cord-cerebrospinal fluid (CSF) interface, and a custom written automated algorithm tracked the edge of the cord inferiorly from this point. Voxels located at the cord-CSF interface were identified by analyzing signal intensity, which is dependant on the relative proportion of cord and CSF. Motion along the spinal cord (i.e., changes in cord-CSF ratio throughout the cardiac cycle) was quantified by measuring signal intensity fluctuations of those voxels along the cord-CSF interface as previously described.[2] Due to variations in subject height, the vertebral levels (i.e. superior-inferior span) imaged varied. Therefore, when combining the data, the conus medullaris was used as a reference point to align data from individual subjects prior to averaging across all subjects.

Results:

The cervical and upper thoracic regions demonstrated a pattern of oscillatory motion in the anterior-posterior direction, which correlated with the cardiac cycle, and these findings are consistent with previous research.[2] In contrast, the lumbar region of the spinal cord was comparatively motionless in all planes. Thus, a consistent pattern of cardiac-induced, anterior-posterior spinal cord motion arises: significant motion occurs in the cervical region, and this motion is progressively dampened in the caudal direction until it is negligible in the lumbar region (figure 1).

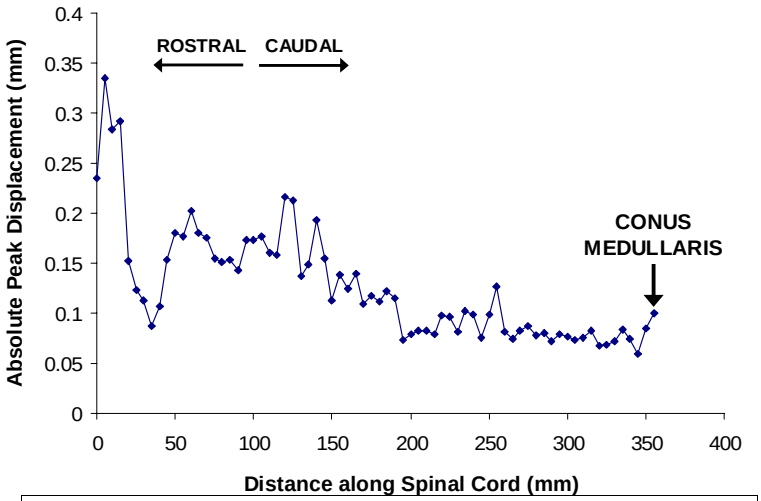

Figure 1. Spinal cord motion from the cervical to lumbar regions.

Conclusion:

These results show how cardiac-induced spinal cord motion changes throughout the length of the cord, demonstrating that this motion error must be accounted for in the cervical and upper thoracic regions, but not the lumbar region of the spinal cord. Importantly, given this lack of motion, the lumbar region represents a "gold standard" control for fMRI and DTI of the upper thoracic and cervical spinal cord – the specific effects of motion on results from theses regions can be determined, thereby validating motion compensation methodologies.

References:

[1] C. R. Figley & P. W. Stroman. *Magn. Reson. Med.* 58: 185-189 (2007).

[2] C. R. Figley & P. W. Stroman. *ISMRM 15th Scientific Meeting,* Berlin (2007).