B0 Fluctuations Within the Human Spinal Cord During Respiration at 7.0 Tesla

David R Pennell[1], Anuj Sharma[2], Henry H. Ong[1,3], and Seth A Smith[1,3]

[1]*Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States,* [2]*Biomedical Engineering, Vanderbilt University, Nashville, TN, United States,* [3]*Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States*

Target Audience: 1) Imaging scientists interested in high field cervical spinal cord imaging and 2) the High Field Systems and Applications Study Group of the ISMRM

Purpose: Previous studies have evaluated fluctuating B0 during respiration within the human brain at 7.0 T [1]. Similar evaluations have been performed at clinical field strengths of 1.5 T and 3.0 T and have established the importance of compensating for bulk susceptibility changes due to respiration in imaging techniques susceptible to slight B0 variations such as echo planar imaging (EPI) and spectroscopy [2-4]. Changes in B0 due to respiration at 7.0 T has yet to be evaluated within the human spinal cord at high field, yet the impact of field fluctuations on the overall spinal cord image quality cannot be ignored. The purpose of this study is to quantify the magnitude of B0 variation at the level of the cervical spinal cord due to respiration at 7.0 T.

Methods: Data Acquisition: Data was collected in one healthy volunteer using a 7.0 T Philips MR scanner (Philips Healthcare, Cleveland, OH) and was approved by the IRB. A 16-channel spinal cord receive array with quadrature transmission (NOVA Medical, Wilmington, MA) was utilized for imaging. Sagittal T2* weighted (T2*-W) multi-slice two-dimensional gradient echo (GRE) was acquired for localization with the following parameters: field-of-view (FOV) = 180x180 mm^2, repetition time (TR) = 350 ms, echo time (TE) = 5.3 ms, slices = 7, slice thickness = 3 mm, resolution = 1x1x3 mm^3, number of signal averages (NSA) = 6, SENSE acceleration factor = 2, acquisition time (TA) = 3 minutes. Single slice multi-echo gradient echo (ME-GRE) was aligned to the middle T2*-W slice with the same geometric orientation to bisect the cervical spinal cord. B0 maps were measured using the double echo-time method [5]. Images for the two echoes were acquired using a GRE sequence with TR = 150 ms, TEs = 3.0, 3.1, ms, resolution = 3x3x3 mm^3, TA = 10s, during breath-hold conditions of inspiration and expiration. One GRE image was obtained per breath-hold. To avoid B0-shim recalculations shim values calculated by the scanner were kept the same. Data Analysis: Phase maps were obtained from the complex Fourier conjugate-phase reconstructed images. As illustrated in Fig. 1A maps suffered from severe phase wraps. Unwrapping was performed using iterative Laplacian based algorithm [5]. Unwrapped phase maps (Fig. 1B) from two echo-times were subtracted to get estimate of phase accumulated due to B0 variations. Maps were converted to frequency-offset maps by dividing the TE difference of 0.1 ms (Fig. 1C). To quantify the B0 variations along the spinal cord during inspiration and expiration ROIs were manually drawn at each vertebral level within the spinal cord, pons and cerebellum as illustrated in Fig. 2. Mean frequency-offsets were calculated inside each ROI (Fig. 3) during each state.

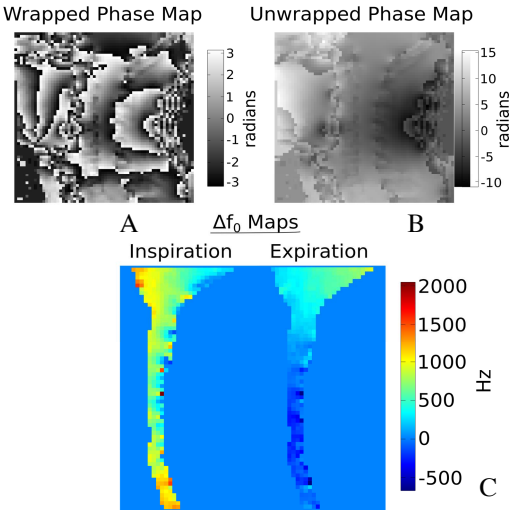

Figure 1. Phase maps wrapped (A) unwrapped (B) and F0 (C)

Results: Large-scale frequency shifts were measured along the base of the brain stem and cervical spinal cord during inspiration and expiration (Fig. 1C). Mean frequency shifts during inspiration varied 1100 Hz while mean frequency shifts during expiration varied 800 Hz. Small scale variations were measured within the pons, cerebellum and upper cervical cord with increasing field shifts as the cord is observed inferiorly reaching maximum frequency shift of 1300 Hz at C7-T1. During expiration small-scale frequency shifts are observed within the pons, cerebellum, C1 and C2 with slight negative frequency shifts measured from C3 to T1.

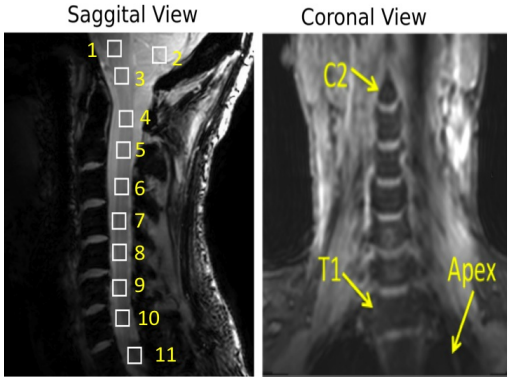

Figure 2. GRE images depicting ROIs and anatomy

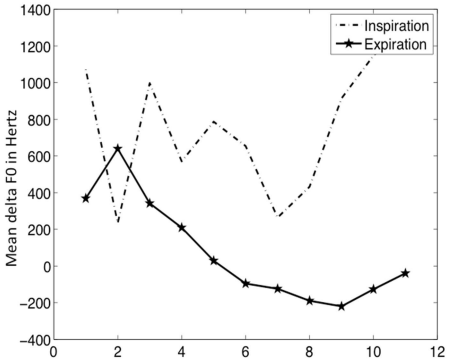

Figure 3. Mean frequency shift of ROIs

Discussion and Conclusion: This experiment quantitatively demonstrates large-scale frequency shift variations observed in the cervical spinal cord due to respiration at 7.0 T. The maximum frequency shift was measured during inspiration at the C7-T1 junction at 1300 Hz however, smaller-scale variations on the order of 150-200 Hz were observed throughout the cord at the posterior aspect of the cord adjacent to the spinous processes of C1-C7. The large-scale variation at C7 is hypothesized to be due to the proximity of the lung apices bilaterally (Fig. 2). Frequency variations of large magnitude due to respiration can be detrimental to experiments utilizing EPI and spectroscopy techniques and must be appropriately corrected. Future Work: We aim to collect more data points with this technique to evaluate other factors influencing frequency shift including body habitus and motion due to swallowing and pulsatile flow.

References: [1] Van de Moortele et al. *MRM* **47:** 888 (2002). [2] Raj et al. *Phy. Med. Bio.* **46:** 3331 (2001). [3] Raj et al. *Phy. Med. Bio.* **45:** 3809 (2000). [4] Spuentrup et al. *Eur. Radioiol.* **13:** 330 (2003). [5] E Schneider et al. *Magn Reson Med.* **18**(2):335-347, 1991 [6] Schofield et al. *Optics Letters* **28:** 1194 (2003).