Simultaneous Diffusion-Weighted MRI of Brain and Cervical Spinal Cord using a 64-Channel Head-Neck Array Coil at 3T

Boris Keil[1], Julien Cohen-Adad[1,2], David A Porter[3], Stephan Biber[3], Keith Heberlein[4], Christina Triantafyllou[1], and Lawrence L Wald[1,5]

[1]A.A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Harvard Medical School, Charlestown, MA, United States, [2]Department of Electrical Engineering, Ecole Polytechnique de Montreal, Montreal, Quebec, Canada, [3]MR R&D, Siemens AG, Healthcare Sector, Erlangen, Germany, [4]Siemens Medical Solution USA, Inc., Charlestown, MA, United States, [5]Health Science and Technology, Harvard-MIT, Cambridge, MA, United States

Target audience: Clinicians (radiologists, neurologists, neurosurgeons), neuroscientists in MRI, coil developers.

Purpose: There is growing interest in diffusion-weighted (DW) MRI due to its specificity to white matter structure, providing quantitative markers in neurodegenerative diseases[1]. However, simultaneous DW-MRI of brain and cervical spinal cord is particularly challenging due to the small cross-sectional size of the cord (requiring high spatial resolution) and the presence of large B_0 inhomogeneities[2] resulting in severe image distortions in diffusion-weighted and functional MRI acquisitions. These issues call for increased detector sensitivity to achieve high spatial resolution acquisitions, and for highly parallelized array coils to accelerate the image acquisition and thereby reduce vulnerability to susceptibility effects when using EPI readout. In this study, we evaluated the suitability for simultaneous brain and cervical spinal cord DW-MRI acquisition using a custom build array coil utilizing 64 channels[3], which allows coverage of both the full brain and cervical spine region. For further mitigation of non-rigid-body motion artifacts, we used a readout-segmented EPI (rs-EPI) acquisition technique with non-linear 2D navigator phase correction and navigator-based reacquisition[4].

Material and Methods: The coil was constructed on an anatomically shaped former consisting of three parts (Fig.1): a large posterior head-neck part comprises 38 elements, an anterior head portion with 18 elements, and an anterior neck section with 4 elements. This 60-channel coil is combined with the upper row of 4 elements of the spine coil to form a 64-channel array covering the head, neck and cervical spine. Data were acquired from a healthy volunteer on a 3T MRI system equipped with 64 receive channels to demonstrate the feasibility of full brain and cervical spine cord tractography with small isotropic voxel size. The rs-EPI sequence was used with the following parameters: five readout segments, TR/TE = 9500/61 ms, matrix:96x128, resolution = 2 mm isotropic, #slices = 64 with sagittal orientation, acceleration factor = 2, b = 800 s/mm^2, 20 diffusion-encoding directions, BW = 1100 Hz/Px TA: 20:23min. DW data were motion corrected (FSL FLIRT) and no distortion correction was applied. We also acquired T1-weighted MPRAGE anatomical data (TR/TE/TI: 1900/2.5/900 ms, matrix: 314 x 320, FoV: 250 x 250mm^2, slice thickness: 0.7 mm, BW:190 Hz/pixel, acceleration factor = 3, TA: 4:43 min).

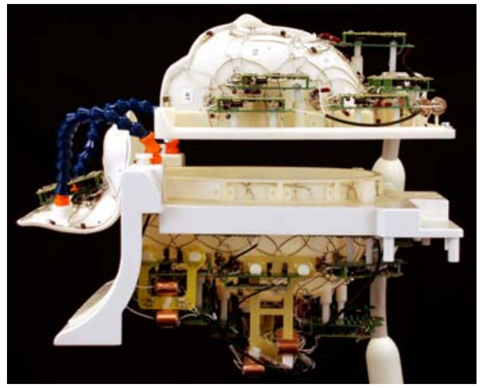

Fig.1: Customized Head-Neck-Cspine array coil without housing covers.

Results: Fig 2 shows the full brain and cervical spinal cord tractography from the 2-mm isotropic DW acquisition. The DW images show well aligned correspondence to structural images with minimal distortions from vertebra T1 throughout the cervical spinal cord towards the full brain. This is further evidenced, that the sequence and coil setup are capable of robustly tracking the corticospinal tract at its full length from the motor cortex down to the spinal cord (Fig 2 *right*). A representative slice of highly accelerated structural brain/c-spine images is shown in Fig 3.

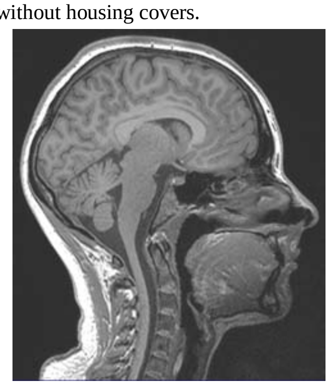

Fig.3: MPRAGE, 3-fold accelerated, TA:4.43min.

Discussion: Previous studies[5,6] have shown that 32 channels improve the quality of simultaneous brain and c-spine imaging. However, in order to serve the neck/c-spine region with detectors, the number of available elements around the brain has to be substantially reduced. This renders brain imaging suboptimal, due to reduced sensitivity and parallel imaging capabilities, compared to 32-channel brain-only array coils. The customized 64-channel coil used in the current study, addresses this limitation by providing sufficient coil elements to allow optimum coverage in both brain and cervical spine region. Functional and multi-parametric (e.g. DW-MRI) imaging of the brain, brainstem and spinal cord will benefit from the high sensitivity of the coil and the high parallel imaging performance will be important for the reduction of susceptibility distortions. The ability to simultaneously perform DW imaging of the full brain and spinal cord will be of major interest for improving clinical diagnosis for neuro-degenerative diseases, such as multiple sclerosis and amyotrophic lateral sclerosis, where the spinal cord is heavily involved.

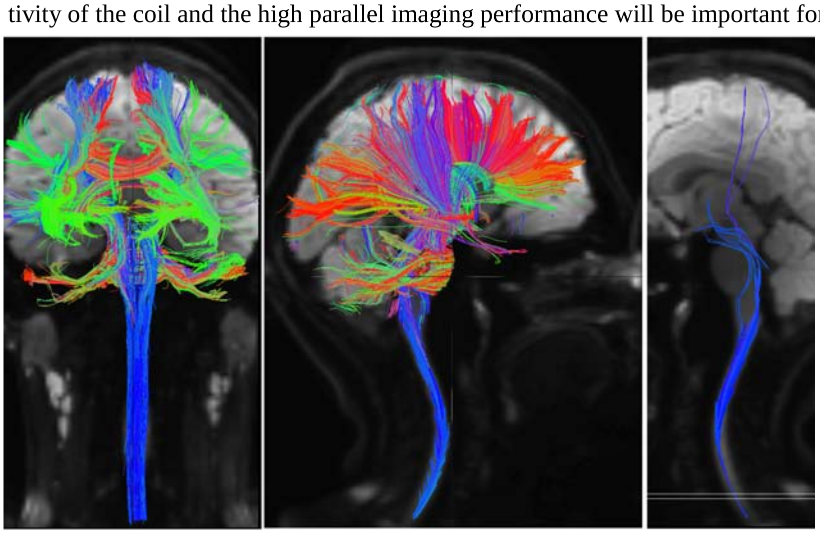

Fig.2: *Left and middle:* Full brain and cervical spinal cord tractography. *Right:* Tractography seeded from the T1 level, showing full tracking of the corticospinal pathway.

Conclusion: In this study, we have demonstrated a fast and robust acquisition of simultaneous brain and cervical spine DW data using a customized 64-channel head-neck array coil. The coil provides high sensitivity in the neck and cervical spine regions, while maintaining the same sensitivity in the brain region as dedicated 32-channel head coils. The highly parallel coil is therefore well-suited to combined brain and neck studies.

References: 1. Thurnher MM et al., Semin Roentgenol 2006; 41:294-311. 2. Bieber S et al. ISMRM 2012 p. 2746. 3. Keil B et al. ISMRM 2011 p.160. 4. Porter DA & Heidemann RM MRM 2009; 62:468-475. 5. Cohen-Adad J et al. ISMRM 2010 p.1491. 6. Cohen-Adad J et al. MRM 2011;66"1198-1208.

Acknowledgement: National Institutes of Health's Grants: U01MH093765 and P41RR14075.