High resolution anatomical imaging of the spinal cord at 7 T

E. E. Sigmund[1], C. Hu[1], G. Suero[1], and J. Helpern[1]
[1]Radiology, New York University Langone Medical Center, New York, NY, United States

Background

Ultra-high magnetic field (7 T) full body MRI scanners are becoming increasingly common in imaging centers worldwide. Certain brain imaging applications (e.g. susceptibility-weighted imaging (SWI)) have low echo times and field-dependent contrast both highly suited to 7T, resulting in a powerful microscopy. The spinal cord, which has only recently been imaged at 7 T [1], is another area where high field MRI may be a great boon to the assessment of such pathologies as multiple sclerosis [2,3], amytrophic lateral sclerosis [4], spondylosis [5], or spinal cord injury [6,7]. This work presents results of coil development and protocol optimization for high resolution 7 T spinal cord imaging.

Methods

A single-channel loop coil and a 4-channel array coil (Fig.1, Rapid Biomedical, Inc.), both transmit/receive design, were employed for anatomical spinal cord imaging in a Siemens full body 7 T system. N = 12 healthy volunteers were scanned at 7 T (4 w/ loop coil, 8 w/ array coil) with approval of the local IRB. N = 6 of the array coil volunteers were also scanned in a Tim Trio 3 T scanner with standard coils (2-ch neck + 8-channel spine array). 7 T axial anatomical imaging used a FLASH (gre) sequence (TR/TE = 500 / 4.9 ms, α = 40°, 832 x 1024 x 5 matrix, 0.18 x 0.18 x 3 mm voxel) and a T2-weighted TSE sequence (TR/TE = 3290 / 11 ms, 660 x 832 x 5 matrix, 0.22 x 0.22 x 3 mm voxel, turbo factor 17, 2 avgs., α = 160°). 3 T axial FLASH imaging was also performed (TR/TE = 514 / 7.4 ms, α = 20°, 320 x 240 x 25 matrix, 0.6 x 0.6 x 3 mm voxel) Gray/white matter volumetric analysis for FLASH images used ImageJ.

Figure 1: 7 T cervical spine coils. Left : single-channel loop. Right: 4-channel surface array.

Results

Figure 1 shows photos of two 7 T coils. The loop coil is placed under the patient in prone position, while the array coil cradles the neck Figure 2 shows FLASH axial (0.18 mm) and sagittal (0.26 mm) images acquired with the loop coil, showing longitudinal coverage of C1-C7 region and good axial cord sensitivity. Figure 3 shows axial FLASH and TSE results with the array coil. Excellent spatial detail is observed, differentiating gray/white matter tissue, dorsal and ventral nerve roots, denticulate ligaments, dura mater, arachnoid sheaths, and rostral-caudal blood vessels. TSE images show some T2 blurring, but also CSF suppression that reveals underlying structures. Figure 4 shows comparison of manually segmented gray matter and whole cord tissue volumes in several matched cervical spine slices of FLASH acquisitions in the same 6 subjects at 3 T and 7 T. At 3 T only total cord volume is measured, while at 7 T white and gray matter sections were differentiated. The correlation between matched slice volumes at 3 T and 7 T for the subject group indicates good agreement (m = 0.97). Furthermore, the gray matter volumes, measurable only with the high resolution 7 T FLASH protocol, are observed to occupy approximately 25 ± 1 % of the total cord cross-section in the cervical region.

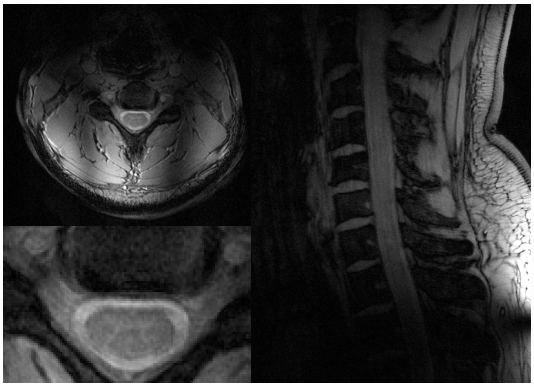

Figure 2: Cervical spine T2-weighted images at 7 T acquired with the surface loop coil.

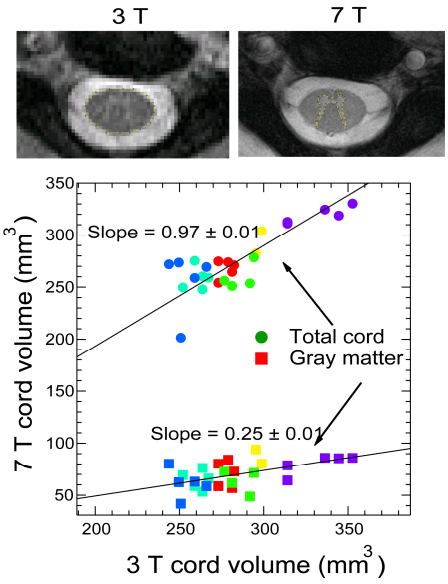

Figure 4: Comparison of spinal cord volumetric measurements in same volunteers at 3 T and 7 T.

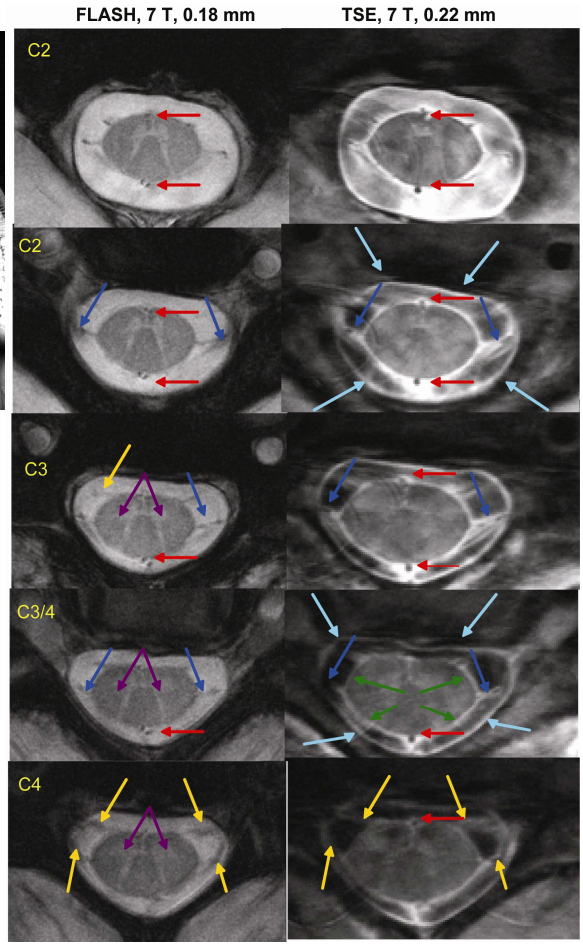

Figure 3: C-spine MRI at 7 T (4-ch array) with T2 FLASH and TSE sequences. Labeled structures : dorsal/ventral nerve roots (yellow), gray matter anterior horn (purple), denticulate ligament (blue), dorsal/ventral blood vessels (red), dura mater (cyan), arachnoid (green).

Discussion

The high resolution achievable at 7 T allows detailed volumetrics that have great potential in tracking morphological changes secondary to myelopathy, following injury, or during recovery. Also, the secondary structures illustrated in Figure 3 (denticulate ligament, dorsal/ventral nerve roots, dura mater, etc.) may assist diagnosis of pathologies unique to these smaller anatomies. This information may also supplement surgical planning in the highly sensitive cases of decompression or repair.

References: 1. Bae K,ISMRM 2009 April; Honolulu. p 632. 2.Ohgiya Y, European Radiology 2007;17(10):2499-2504. 3. Ciccarelli O, Multiple Sclerosis 2007;13:S190-S190. 4. Valsasina P, ISMRM 2006 May; Seattle. p 986. 5. Demir A, Radiology 2003;229(1):37-43. 6. Ellingson BM, Ann Biomed Eng 2008;36(2):224 236. 7.Mahmood NS, Spinal Cord 2008;46(12):791-797.