FAST SIMULTANEOUS ACQUISITION OF HIGH-RESOLUTION BRAIN AND CERVICAL SPINAL CORD T1W IMAGES TO MEASURE SPINAL CORD ATROPHY: METHODS AND VALIDATION

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Introduction:

Spinal cord cross-sectional area (SCA) is an important marker of disease progression in multiple sclerosis (MS) possibly reflecting the rate of axon/myelin loss (1). T1 weighted (T1w) 3D imaging using dedicated spine array coils for signal reception is the current established standard for non-invasively determining the SCA (1). We set out to develop a new imaging protocol for a fast, comprehensive assessment of the brain and cervical spinal cord in traumatic spinal cord injury (SCI), currently implemented as two separate acquisitions. In order to minimize scan time, we simultaneously acquired brain and cervical SC images using a T1w 3D MDEFT sequence in combination with an 8-channel head coil with good coverage of the cervical cord. We assessed the accuracy and precision of this new technique by comparing it to the established standard at the clinical field strength of 1.5T.

Methods:

Data acquisition Ten control subjects and nine subjects with traumatic SCI at level C 5- C7 were scanned on a 1.5T Siemens Sonata after obtaining written informed consent as supervised by the local Ethics committee. The new imaging approach used an 8-channel head receive coil (Siemens/MRI devices) for signal reception, body RF coil for transmission, and a 3D MDEFT sequence that is well established for high-resolution brain imaging and morphometry (2) with the following parameters: 176 sagittal partitions, 256x256 image matrix, FOV = 256x256 mm^2, isotropic 1 mm^3 resolution, TR/TE/TI = 12.24 /3.56 /530 ms, BW = 106 Hz/Px, $\alpha = 23°$, 13.43 mins. acquisition time. In contrast to the original implementation described in (2), spin tagging in the neck was not applied to preserve the signal in the region of the SC. For comparison with the established standard, a T1w 3D MPRAGE (3) protocol was scanned with the following parameters similar to (1) and using the vendor's standard spine coil array: 60 sagittal partitions, 256x256 image matrix, FOV = 250x250 mm^2, 0.98x0.98 mm^3 resolution, TR/TE/TI = 1300/ 5.19/ 450 ms, BW = 130 Hz/Px, $\alpha = 20°$, acquisition time 5.5 mins. To assess the scan-rescan stability of the new technique, two 3D MDEFT scans were acquired on different days (> 1 month apart). An additional 3D MPRAGE scan was acquired on the same day as the second 3D MDEFT scan.

Data processing Two observers (PF, CD) independently measured the SCA on a series of five contiguous axial slices (3mm slice thickness) using a semi-automated segmentation as described by (1). Briefly, the C2 disc served as the caudal landmark and slices were reformatted perpendicular to the spinal cord. A region of interest was drawn around the cord CSF space and the cord itself on each slice. Mean signal intensities in the two ROIs informed a threshold-based automatic segmentation of the cord. The SCA was automatically estimated in each slice and averaged. As measures of precision of the MDEFT approach, the coefficient of variation (CV) and standard deviation (SD) of the average SCA were determined from the scan-rescan pairs. The dependence of measured SCA on the imaging method (brain+spine MDEFT vs. spine MPRAGE) and observer (PF vs. CD) was assessed by a 2x2 repeated measures ANOVA (SPSS Statistics 17.0) with $p < 0.05$ significance threshold. Data were further explored using Bland-Altman plots (4).

Results:

The spinal cord was well delineated from the surrounding CSF in the MDEFT images down to the level of C5 due to the MDEFT's intrinsic suppression of long T1 signals (5). Reduction of SCA in subjects with SCI at cervical level C2 could be detected clearly (see Fig. 1). Both observers achieved similar precision with SD = 4.49 mm^2/3.48mm^2 and CV = 6.6%/5.2%. The ANOVA revealed a main effect of observer ($F = 5.75$, $p = 0.028$) and interaction between observer and scan method ($F = 6.08$, $p = 0.025$). Post-hoc paired t-tests indicated that the interaction and main effect can be primarily attributed to a slight observer bias for MPRAGE ($df = 17$, $t=-2.72$, $p = 0.014$). However, the detected bias was small (2.01 mm^2) and negligible compared to the rather large changes due to SCI (~30 mm^2). No bias was observed for MDEFT vs. MPRAGE ($p = 0.4$). Good agreement between the MDEFT and the MPRAGE method was also seen in the Bland-Altman plots (for observer PF, see Fig. 2).

Figure 1: Cross-sectional 3D MDEFT images at C2

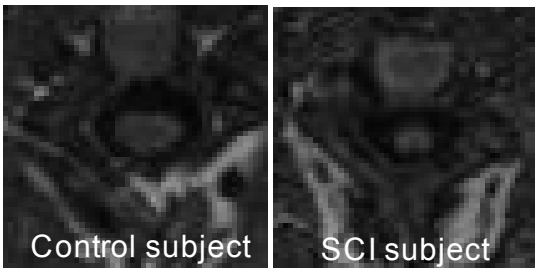
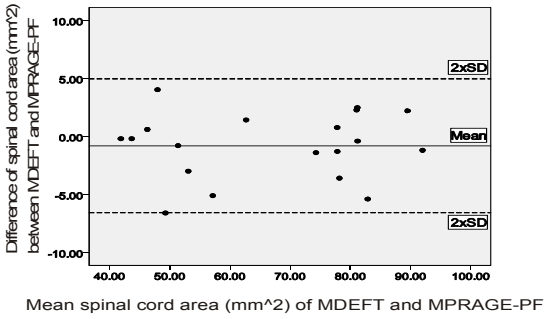


Figure 2: Bland-Altman plot for observer PF



Discussion:

We have implemented a method for fast and reliable imaging of brain mophometry and SCA based on 3D MDEFT scans with an 8-channel receive head coil. The cross-validation with the current established standard based on 3D MPRAGE scans with dedicated spine coils showed good agreement in healthy controls and subjects with SCI. A higher intra-observer CV was observed for the MDEFT (~6%) compared to the intra-observer CV determined for the MPRAGE (~1%) in a previous study on MS (1). The higher intra-observer CV may be present, since in our study scan/rescans were performed in two different scan sessions unlike in the previous study. Further, the C2 region was relatively far away from the gradient isocenter in the brain+SC MDEFT scans, exacerbating potential gradient non-linearity. The proposed method facilitates the comprehensive assessment of volumetric changes in brain and cervical spinal cord after a traumatic SCI. Overall scan time is shortened (14 vs 19 min) and repositioning of the subject and coil adjustment is avoided.

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References: (1) Losseff et al. Brain 1996;119:701-708. (2) Deichmann et al. Neuroimage 2004;21(2):757-767. (3) Mugler and Brookeman Magn Reson Med 1990;15(1):152-157. (4) Bland, Altman. Lancet 1986;327:307-310. (5) Hochmann, Kellerhals. Journal of Magnetic Resonance 1980;38:23-39.