Quantitative evaluation of spinal cord tissue damage in MS patients using Gradient Echo Plural Contrast Imaging

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Introduction: As an important part of the CNS evaluation, spinal cord imaging is valuable in both diagnosis and ongoing evaluation of patients with multiple sclerosis (MS) (1). However, assessment of spinal cord damage using MRI lags behind the development of brain methodology. A Gradient Echo Plural Contrast Imaging (GEPCI) technique (2,3), providing substantial improvement in image quality and MRI acquisition time as compared to clinical sequences, has been used to quantitatively evaluate white matter tissue damage in brains of MS patients (4). Herein, we present preliminary results using GEPCI technique to detect tissue damage in spinal cord of MS patients compared to normal subjects. This is an important step in development of the GEPCI technique as a comprehensive tool for quantifying the extent of tissue damage of the whole CNS, and monitoring MS disease progression.

Methods and Data Analysis: Data from the cervical spinal cord of healthy volunteers and relapsing-remitting MS patients were acquired using a Siemens® 3.0T Trio MRI scanner. A 3D version of GEPCI sequence was used with high isotropic resolution of 1x1x1 mm^3 and 11 gradient echoes (8min32s acquisition time). Further effective resolution enhancement was achieved with zero-filling in the k-space. A set of five standard clinical 2D turbo spin echo T1w and T2w images were acquired with a total imaging time of 16 min. Saturation band was applied on the anterior portions of the torso, to suppress motion artifacts. GEPCI technique simultaneously generates naturally co-registered quantitative T2* and R2*=1/T2* maps, along with T1-weighted (T1w) images. Data were analyzed using Matlab®. Isotropic resolution allows image reconstruction in arbitrary plane, thus providing great advantages over clinical methods. Mask for spinal cord area including both white matter and gray matter was obtained with segmentation based on the T1w-GEPCI images. R2* histogram of the whole cord is generated using a bin width of 0.3 s^{-1} ranging from 0 s^{-1} up to 30 s^{-1}.

Results and Discussion: Figure 1 below shows examples of GEPCI-T1w (left column), T2* map (middle column) and R2* map (right column) of the spinal cord. Bottom row is the sagittal view; Upper row - magnified views of the transverse cut through the spinal cord corresponding to the red line on the sagittal view. All images are reconstructed from the same GEPCI 3D data set. The image on the right represents anatomy of spinal cord at a similar level; characteristic butterfly pattern of the grey matter is clearly seen on axial GEPCI R2* map. Remarkably, the grey matter is also seen on the sagittal views (bright T2* / dark R2* lines inside the spinal cord).
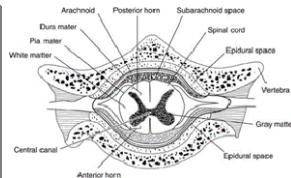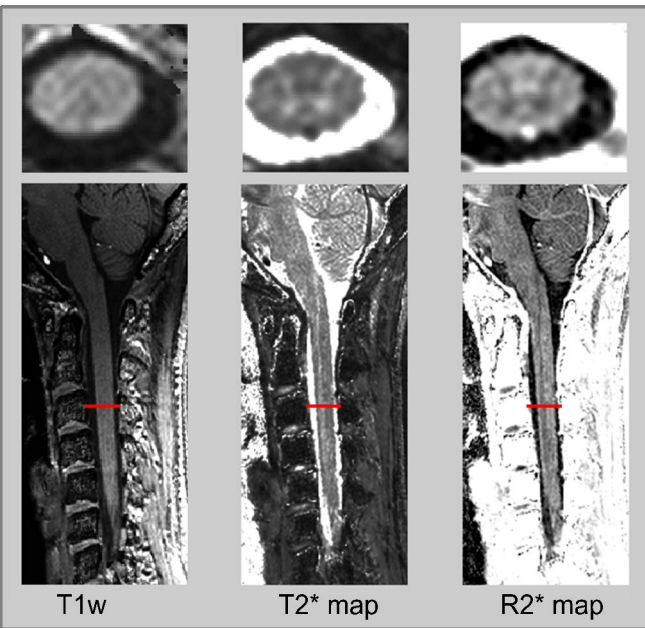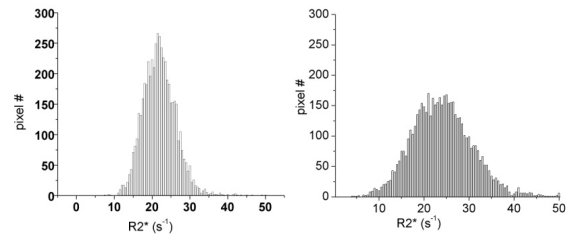

| T1w | T2* map | R2* map |

Figure 2 (below) shows examples of the R2* histograms of c-spinal cord of a healthy control (left) and MS subject (right). The width of the distribution (variation of the R2* values) of RRMS subject (12.9 s^{-1}) is substantially greater than the R2* variation of control subject (8.32s^{-1}) suggesting diffuse MS tissue damage.

Spinal MS lesions are rarely depicted as hypointense on clinical T1w images, which indicates that the pathological changes in the tissue are not sufficient to produce contrast in T1w images(1). Similar situation is seen in our GEPCI-T1w image. However, quantitative R2* histograms shown in Fig. 2 clearly differentiate normal from MS tissue. One of the problems with the clinical standard T2/T1 weighted images is that the intensity of the image is affected by the RF coil sensitivity and homogeneity of the RF field. Indeed we also observe image intensity variation (both up-to-bottom and left-to right) in our T1w images (Fig.1, left). However, as seen in Fig. 1 (middle and right), the R2* and T2* GEPCI maps, being quantitative, are exempt from the sensitivity problem.

Conclusion: In this study, we demonstrated the capability of extending GEPCI technique to spinal cord imaging in general and quantitative evaluation of tissue damage in MS. High quality images were collected twice faster compared to standard clinical MS protocols. As a quantitative technique, GEPCI holds promise toward comprehensive characterization of MS abnormalities in the spinal cord. Also note that the cerebellum and brain stem areas showed very good contrast with our resolution, which further strengthens the promise for GEPCI technique to characterize the whole CNS.

References: 1. Lycklama G, et al., Lancet 2:555-562, 2003; 2. Yablonskiy DA. Radiology 217: 21, 2000; ISMRM (2000); 3. Bashir A and Yablonskiy DA, ISMRM (2006); 4. Sati P, Cross AH, Luo J, Hildebolt CF, and Yablonskiy DA. Neuroimage 51: 1089-1097, 2010.