Gradient Echo Plural Contrast Imaging for Evaluating Multiple Sclerosis

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INTRODUCTION: Magnetic resonance imaging is well established in diagnosis and evaluation of patients with multiple sclerosis (MS). The extent of MS is evaluated as lesion load (volume of lesions) on T1 and T2 weighted images. Often FLAIR is used to enhance MS lesion contrast as MS lesions often appear similar to CSF. Although above mentioned methods provide high sensitivity for detection of MS lesions and have reasonable correlation with neurological disability and cognitive impairment they lack the pathologic specificity (1). In addition, these conventional sequences are unable to detect subtle changes in normal appearing white matter. Quantitative maps of tissue transverse relaxation time T2 have demonstrated a better correlation with the pathology (2). Also the T2 values of the normal appearing white matter could be very useful for early diagnosis and evaluating the extent of the disease and therapeutics. In MRI spin echo multi-echo pulse sequences are used to create T2 maps, however, the spin echo based T2 mapping approach requires very long acquisition times, up to 4.5 hours in one particular MS study (2). Also high RF energy deposition restricts such applications, especially at high fields. These factors limit clinical applications of SE-based T2 mapping techniques. Here we demonstrate that previously introduced Gradient Echo Plural Contrast Imaging (GEPCI) technique (3-5) that allows simultaneous acquisition of T2 maps, T1 weighted images and quantitative GEPCI-FLAIR images, may provide clinical platform for quantification of MS lesions. Results are also compared with standard clinical T1 weighted, T2 weighted and FLAIR images obtained on the same subjects. Superior image quality obtained with GEPCI approach in a shorter amount of time as compared to clinical sequences is also demonstrated.

METHODS: All GEPCI experiments were performed on Siemens 1.5 T Magnetom Sonata system with a 3D multi-gradient-echo sequence. *In vivo* images of four MS subjects were acquired with the following parameters: in plane resolution of 1×1 mm^2, slice thickness = 2 mm, TR = 100ms and flip angle = 30^o. A total of 27 GEPCI gradient echo images with initial TE = 3.4ms and echo spacing of 3.4ms were obtained in each MRI scan. Total scan time 8.5 minutes. Phase difference images between the 1st and 6th echoes were used to generate field maps. Magnetic field gradients in each voxel were calculated by fitting a 3-dimensional 1st order polynomial to field map data corresponding to a given voxel and surrounding neighbors. These field gradients were then used to calculate the signal decay due to field inhomogeneities as described in (5). A single exponential function with field inhomogeneity correction was used to fit magnitude multi-gradient-echo data to generate quantitative T2 maps from gradient echo dataset. Given the choice of TR and flip angle for these experiments the fitting procedure also generated a co-registered T1 weighted images. GEPCI generated T2 maps were thresholded (cut-off T2=200 ms) to remove the CSF regions and generate quantitative GEPCI-FLAIR images. Standard clinical T1 and T2 weighted as well as FLAIR images were also acquired for these subjects with the following parameters: in-plane resolution = 1×1mm^2, slice thickness = 5mm. Other parameters were as follows: T1 weighted spin echo images with TR/TE = 510/11ms, T2 weighted turbo spin echo images with TR/TE = 4000/88ms; FLAIR with TR/TE/TI = 10000/140/2500 ms. Scan time for each sequence approximately 4 minutes.

RESULTS: Fig. 1 shows representative images from one subject. The upper row represents standard clinical T1 weighted image (a), T2 weighted image (c) and FLAIR image (e). MS lesions appear as hypo-intense signal on T1 weighted and hyper-intense signal on T2 weighted and FLAIR images. The lower row represents analogous images obtained with GEPCI approach. First we note that GEPCI T1 weighted image has much higher contrast to noise even though it has higher resolution as compared to clinical T1 weighted image. This is naturally achieved in GEPCI technique because T1 GEPCI image is a result of fitting procedure obtained from multiple gradient echo images. Comparison of standard clinical T2 weighted image and a T2 map generated by GEPCI (Figs. 1c and 1d) demonstrates a similar global lesion distribution. However, it can be seen that the lesions are more delineated and detailed in GEPCI images. Since CSF has long T1 and T2 as compared to tissue, clinically FLAIR sequence is used to suppress CSF signal with inversion pulse in order to enhance lesion delineation from CSF. GEPCI creates a T2 map therefore a threshold can be applied to T2 map to remove tissue with long T2, i.e. CSF. Figs. 1e and 1f show comparison of FLAIR images with quantitative GEPCI-FLAIR images obtained from GEPCI T2 map where a threshold is applied to remove the CSF. Quantitative GEPCI-FLAIR image demonstrates structural differences in MS lesions that are not apparent in standard clinical FLAIR images. Figure 2 further elaborates on this issue by showing the GEPCI-FLAIR created T2 map in color-scale. It is clear that the lesions have a distribution of relaxation times which may correlate with pathology.

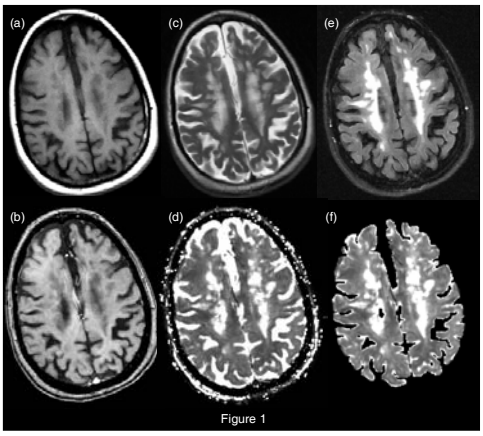

Figure 1

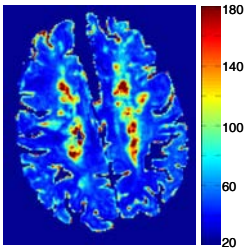

Figure 2

CONCLUSION: We have demonstrated an application of a new MRI method (GEPCI) for multiple-sclerosis evaluation. The method allows generating quantitative T2 maps, quantitative FLAIR images and T1 weighted images from a single scan. All images are naturally coregistered which is important in MS as the lesions show changes in both T1 and T2 contrast. These GEPCI images are acquired at higher resolution, higher SNR in a shorter scanning time as comparable qualitative clinical scans. Another advantage of the approach is that high resolution quantitative T2 maps can be generated in a fraction of time it takes for comparable spin echo based techniques. These quantitative T2 maps may provide invaluable information in evaluating MS.

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