Detecting Cortical Lesions in MS Tissue with Gradient Echo Plural Contrast Imaging

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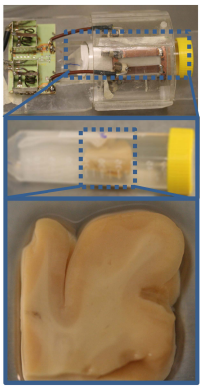
Introduction: Although most imaging research in Multiple Sclerosis has focused on the white matter, pathology can also be found in gray matter, including cerebral cortex. MS symptoms and signs including cognitive impairment, fatigue, and seizures have been linked to gray matter involvement (1). Conventional MRI techniques that are routinely used to detect MS lesions are T1 and T2 weighted spin-echo images and FLAIR, which detect white matter lesions well, but miss most cortical lesions, as reported in a postmortem tissue-MRI correlation study (2) at field strength of 1.5 T. Though higher fields will result in increased detectability of both cortical and WM lesions (3), these imaging techniques will suffer from high specific absorption rate (SAR), especially at 7.0 T. Gradient Echo Plural Contrast Imaging (GEPCI) is a technique based on multi-echo gradient echo sequence, which has very low SAR. It generates T1w, T2* and frequency maps with one acquisition (4) and already proved useful in quantifying tissue damage in WM lesions in MS (5). In this pilot study, we evaluated GEPCI as a way to detect and quantify cortical lesions.

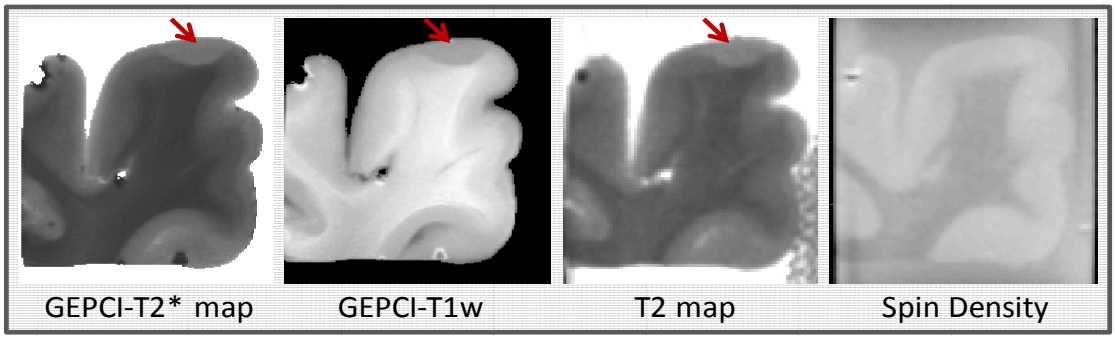
Material and Methods: Acquisition: Brain tissue of an *ex vivo* MS patient was scanned on a Varian 4.7 T MRI. Sample



prepared as figure on the left. A 3 cm diameter bird cage coil was used to obtain a 3D version of the multi-echo gradient echo sequence with a resolution of 0.11 x 0.11 x 0.5 mm^3, FOV of 40 x 40 x 8 mm^3 and 8 gradient echoes (TR = 200 ms; minTE = 4.58 ms; delta-TE = 7.6 ms; bandwidth = 40 kHz/FOV; FA = 60°, acquisition time = 13 min). 2D T2 weighted images were also acquired with spin echo sequence at different TE separately, (TR = 4000 ms; TE = 13 ms, 50 ms; acquisition time = 8 min x 2) and slices of same orientation.

Image Analysis: GEPCI data were analyzed assuming mono-exponential signal decay and attenuation due to macroscopic field inhomogeneities, describing by *F*-function as discussed in (6): $S(TE_n) = S_0 \cdot e^{-R2^* \cdot TE_n} \cdot F(TE_n)$. The fitting to magnitude data produces two naturally co-registered basic GEPCI images: quantitative T2* = 1/R2* map and T1-weighted images (S_0). The frequency maps are obtained from phase data and used for calculation of *F*-function (6). As for T2 mapping, T2 weighted images at two echo times were fit by a mono-exponential decay: $S(TE_n) = S_0' \cdot e^{-R2 \cdot TE_n}$, which results in a T2=1/R2 map and a Spin Density image (S_0'). All data were Hann-filtered to improve SNR before fitting procedures.

Results & Discussions: As shown in figure on the right, T2* map, T1-weighted image and T2 map showed very well defined cortical lesion (red arrows). Sub-cortical structures are also observed on GEPCI images and T2 map. The contrasts in cortical structures are not seen on the Spin Density images. It has been reported that focal cortical lesions are often extensive in MS (7). Unfortunately, cortical lesions are often completely missed with conventional MRI techniques, due to limited signal contrast between cortical grey matter and lesions. Double Inversion Recovery (DIR) has been reported to have significantly improved detection of cortical lesions (2), but it is often difficult to distinguish true lesions from artifacts using DIR, and problems are anticipated with high energy deposition at high field.



Conclusions: In this pilot study, we have demonstrated that GEPCI technique is sensitive to cortical lesions and sub-cortical structures on *ex vivo* MS tissue. GEPCI holds much promise for the future, as the multi-echo gradient echo sequence upon which GEPCI is based has no problem with energy deposition at high field and it is very rapid; one would have to trade off resolution and/or SNR significantly to creates maps of T2 with similar amount of time.

References: 1) Pirko I, et al., Neurology (2007) 68:p634; 2) Geurts JJ, et al., Radiology (2005) 236:p254; 3) Mainero C, et al., Neurology (2009) 73:p941; 4) Yablonskiy DA, ISMRM (2000); 5) Sati P, et al., Neuroimage (2010) 51:p1089; 6) Yablonskiy DA, Magn Reson Med (1998) 39:417-428; 7) Kutzelnigg A, et al., Brain (2005) 128:p2705.