T2* Mapping in the Brain using a Prospective Motion Corrected Segmented-EPI sequence.

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Purpose: T2* contrast is highly sensitive to susceptibility changes, and therefore correlates with important diagnostic markers such as iron concentration [1] and blood oxygenation [2]. Recently, T2* mapping has been demonstrated to provide fully quantitative maps of iron concentration [3,4] and also for Myelin mapping [5]. Typically, T2* weighted images are acquired with a gradient echo sequence at multiple echo times. This approach provides high resolution but at a cost to scan time. EPI approaches have also been employed [6,7], which offer a speed up in acquisition time. For an accurate T2* determination, motion correction is essential to avoid mis-registration between images of different echo times, as well as artefacts caused by motion between EPI segments. In this work, a multi-echo, segmented EPI sequence enabled with prospective motion correction using an in-bore camera system [8] is implemented and applied to T2* map acquisition in the human brain.

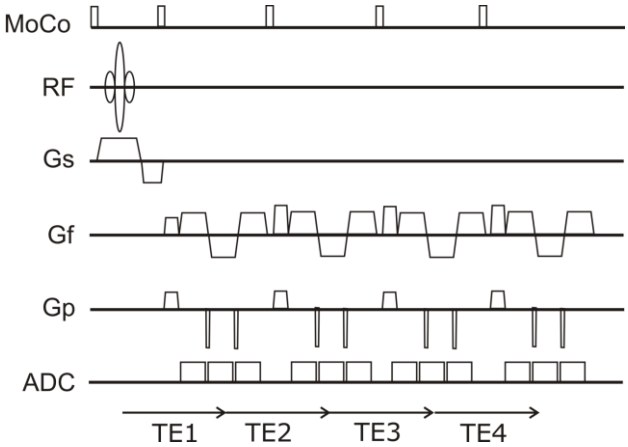

Fig1. Sequence diagram of the EPI sequence over 1 TR and 4 echoes. Sections where the gradients and RF are update by motion correction (MoCo) are shown.

Methods: All images were acquired on a Siemens 3T Trio system (Siemens Healthcare, Erlangen, Germany) using a 32 channel head coil. Multi-echo segmented EPI imaging (Fig. 1) was performed on 3 healthy subjects. Acquisition parameters: 256x256 matrix, in plane resolution of 1x1mm^2, 5mm slice thickness. Bandwidth 976Hz/px, EPI factor 3 leading to 85 segments. TR=115ms. In total, 12 echo times were used ranging from 5.5-90.3ms, with $\Delta TE \approx 7.1$ms. Total acquisition time was 12s per slice. Subjects underwent 4 EPI scans: scan 1 was performed with motion correction whilst the subject was instructed to perform slow head movements; scan 2 was performed with motion correction with the head as still as possible. This was repeated for scans 3 and 4, but without motion correction. Offline, T2* maps were calculated in MatLab (The Mathworks, USA) by fitting a single exponential decay to the image data using a weighted least-squares algorithm.

Results: T2* maps acquired during head motion can be seen in Fig 2 without and with prospective motion correction. It can be seen that without correction, image quality is significantly reduced. Quantitatively, the average T2* of white matter were compared from maps from with and without motion correction whilst the subject remained stationary. With motion correction, white matter T2* was determined to be 49±13ms, compared to 60±13ms without motion correction. These can be compared to 53±5.1ms as discovered in the literature [6]. It can be seen that T2* values are more in agreement with literature values when motion correction is applied.

Discussion: The results show that prospectively correcting an EPI acquisition improves image quality and precision of the T2* values within the brain. However, in general there are other factors to consider when performing real-time correction to an EPI sequence. The first to consider is the sensitivity of the EPI readout to B0 heterogeneity. As the shim coils are not also updated with motion, consequently there are changes to the B0 field within the brain [9]. Secondly is concerning gradient imperfections, such as gradient delays. In the case of a rotation, the logical gradients (slice-select, readout, phase encode) are also rotated. This changes the amount of contribution from the physical gradients, and therefore changes the delay experienced on the logical gradients. This will have consequences for N/2 ghosting. Both the effects of shimming and gradient imperfections are subject to further investigations.

Conclusion: Motion during the acquisition of multi-echo EPI data is highly corruptive and in cases of subject incorporation renders T2* maps uninterpretable. Using prospective motion correction ensures that all slices along the time series remain registered, as well as reducing artefacts arising from motion between EPI segments.

References: [1] Haake *et al.*, MRI 2005;23, [2] Kwong *et al.*, PNAS 1992;89, [3] Peran *et al.*, Hum Brain Mapp 2009;30, [4] Langkammer *et al.*, Radiology 2010;257(2), [5] Hwang *et al.*, Neurology 2010;52, [6] Peran *et al.*, JMRI 2007;26, [7] Triantafyllou *et al.*, PLoS ONE 2011;6(9), [8] Maclaren *et al.*, PLoS ONE 2012;7(11). [9] Maclaren *et al.*, MRM 2013;69.

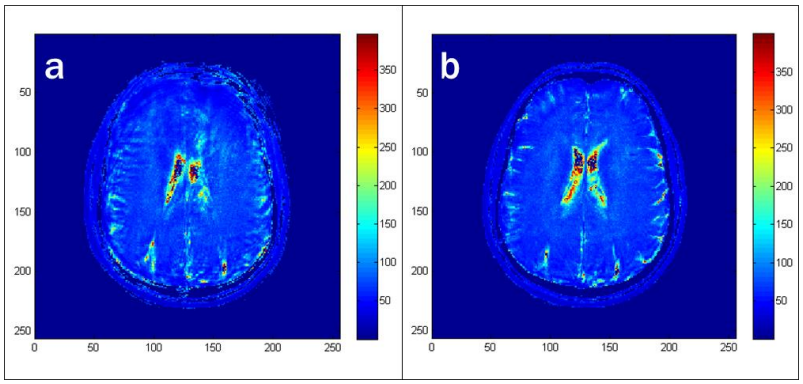

Fig 2. (a) non-motion corrected and (b) motion corrected T2* maps acquired whilst the subject was instructed to perform head motion