Fast T1 Mapping at 7T using Look-Locker TFEPI

E. L. Hall[1], A. M. Al-Radaideh[1], S. Y. Lim[2], S. T. Francis[1], and P. A. Gowland[1]
[1]Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom, [2]Clinical Neurology, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

INTRODUCTION: To monitor tracer kinetics in multiple sclerosis (MS) it is important to be able to measure longitudinal relaxation time, T_1, at high spatial resolution with good coverage across the whole brain, and with high temporal resolution compared to the rate of uptake in lesions (~20-30 minutes [1]). Look-Locker (LL) techniques provide a rapid method of measuring T_1 by acquiring multiple readouts of each recovery [2]. Ultra-high field (7T) provides increased signal-to-noise ratio (SNR) that can be used to increase temporal and spatial resolution, but also lengthens relaxation times which can increase the time required to measure T_1. Here we present LL inversion recovery with Turbo Field Echo Planar Imaging (TFEPI) readout to provide high resolution 1.25 mm isotropic resolution T_1 maps in less than 6 minutes with whole brain coverage. We have initially applied this sequence to monitor the effect of contrast enhancement (CE) in two MS patients.

METHODS: Sequence: The sequence combined a turbo field echo (TFE) and echo planar imaging (EPI) readout to speed up the acquisition (fig. 1). To estimate T_1, an analytical expression was formulated for the steady state, longitudinal magnetisation prior to the j^{th} pulse ($0<j\leq M.N$) corresponding to the centre of k-space in the n^{th} TFE block [4]. Simulations: For robust measurements the sequence parameters (readout flip angle (α), τ, TW, N, M, TI and TA) must be optimized for SNR in the fitted T_1 for a given scan time. A Monte Carlo simulation was performed to estimate errors in the T_1 fits: a signal was simulated and Gaussian random noise was added with mean of 0.01% M_0, the resulting signal was then fitted to estimate T_1. Experiments: All imaging was performed on a Philips Achieva 7.0 T scanner using a head volume transmit coil and 16-ch SENSE receive coil. Phase images were acquired to allow for sign correction of the modulus data. The scan parameters were shot-to-shot interval (SSI) =3s, N=8, M=15, P=3, $\alpha=6^o$, τ=9.1ms, TA=245.4ms, TI = 21ms, TW = 242ms, SENSE= 2, FOV = 200x170x72mm^3, 1.25mm isotropic voxel, total scan time 5mins 45s. Phantoms with different agar gel and gadolinium concentrations were scanned for calibration. Two patients (1 male, 1 female, 24 and 48 y.o.) with Clinically Isolated Syndrome (CIS- early MS) were scanned before and after administration of Gadolinium contrast agent (0.1mmol/kg body weight).

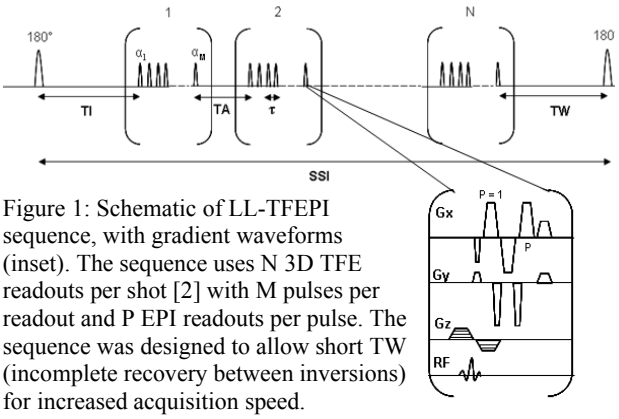

Figure 1: Schematic of LL-TFEPI sequence, with gradient waveforms (inset). The sequence uses N 3D TFE readouts per shot [2] with M pulses per readout and P EPI readouts per pulse. The sequence was designed to allow short TW (incomplete recovery between inversions) for increased acquisition speed.

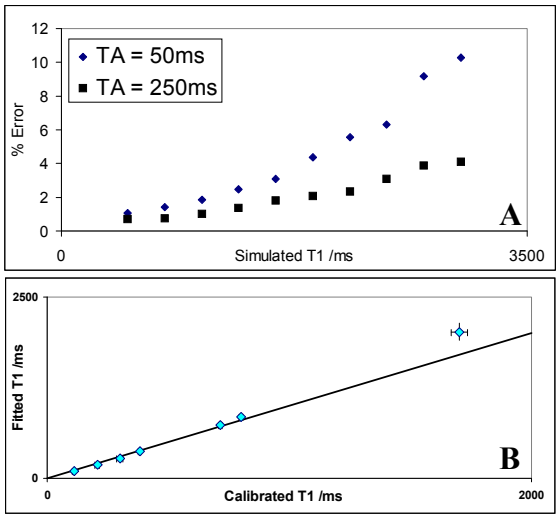

Figure 2: A: Results of Monte Carlo simulations, showing random error in fitted T1 (top) B: Phantom calibration results (bottom).

RESULTS: Simulations showed that random and systematic errors in T_1 fits were improved by increased TW, τ, N and TA and decreased M and α. Fig. 2A shows the effect of TA on the percentage difference between simulated and fitted, T_1. The phantom calibration shows some overestimation of long T_1s (Fig. 2B). Fig. 3A shows an example T_1 map produced for one patient. Fig. 3B shows the change in whole brain T_1 histograms on CE.

DISCUSSION: LL acquisition combined with TFE and EPI readout has been used to acquire a high resolution, large volume coverage T_1 map at 7T in less than 6 minutes, with high SNR (Fig. 3A). Simulations and experiments show that fitted T1 values are improved if sequence parameters are chosen to prevent the magnetization from reaching a steady state too quickly during the recovery. Prior to CE the histograms indicate that the T_1 values for white matter (WM) were ~1100ms and for grey matter (GM) were ~ 1800ms, similar to those found in [5], but long T_1 values were slightly underestimated. Tailored inversion pulses and improved fitting algorithms are now being implemented to address this. The effect of T_1 changing during the acquisition due to CE will also be investigated. CE significantly reduced the T_1 in the GM due to the large blood volume but no enhancing lesions were found in these CIS patients. Future work will use this sequence for the quantitative study of the time course of CE in MS lesions. **REFERENCES:**

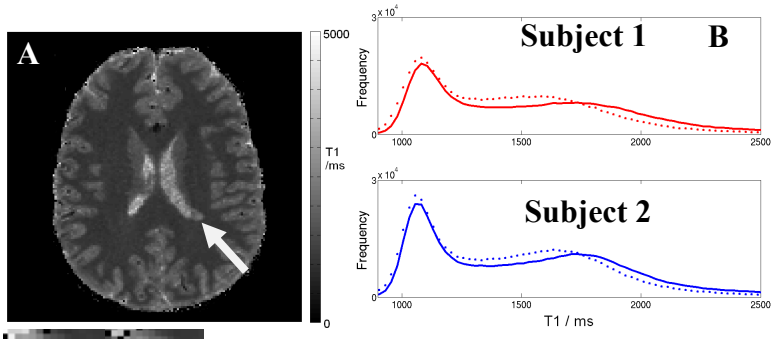

Figure 3: T1 (A) map with periventricular lesion (arrow and inset) (B) histograms before (solid line) and after (dashed line) the administration of contrast agent for each subject. Time after administration of contrast: 22 mins subject 1, 45 mins subject 2.

[1] Filippi MS 6:320-326 2000 [2] Look, D.C., Locker D.R. Rev. Sci. Instr. 41(2):250-251 (1970) [3] Nkongchu, K., Santyr, G. MRI 23:801-807 (2005) [4] Brix et al. MRI 8:351-356 (1990) [5] Wright et al. Magn. Reson. Mater. Phys. 21:121-130 (2008) **ACKNOWLEDGEMENTS:** This work was supported by the MRC.