Fast T1 Mapping at 7T using Look-Locker TFEPI

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INTRODUCTION: To monitor tracer kinetics in multiple sclerosis (MS) it is important to be able to measure longitudinal relaxation time, T1, 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 T1 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 T1. Here we present LL inversion recovery with Turbo Field Echo Planar Imaging (TFEPI) readout to provide high resolution 1.25 mm isotropic resolution T1 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 T1, an approximate expression was formulated for the steady state, longitudinal magnetisation prior to the jth pulse (0<j≤M,N) corresponding to the centre of k-space in the nth 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 T1 for a given scan time. A Monte Carlo simulation was performed to estimate errors in the T1 fits: a signal was simulated and Gaussian random noise was added with mean of 0.01% M0, the resulting signal was then fitted to estimate T1. 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, α=6°, τ=9.1ms, TA=245.4ms, TI = 21ms, TW = 242ms, SENSE= 2, FOV = 200x170x72mm³, 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).

RESULTS: Simulations showed that random and systematic errors in T1 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, T1. The phantom calibration shows some overestimation of long T1s (Fig. 2B). Fig. 3A shows an example T1 map produced for one patient. Fig. 3B shows the change in whole brain T1 histograms on CE.

DISCUSSION: LL acquisition combined with TFE and EPI readout has been used to acquire a high resolution, large volume coverage T1 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 T1 values for white matter (WM) were ~1100ms and for grey matter (GM) were ~1800ms, similar to those found in [5], but long T1 values were slightly underestimated. Tailored inversion pulses and improved fitting algorithms are now being implemented to address this. The effect of T1 changing during the acquisition due to CE will also be investigated. CE significantly reduced the T1 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.