Fast T1 Mapping using modified Double-Inversion Recovery pre-pulse

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INTRODUCTION

The rapid measurement of the longitudinal relaxation time (T_1) would allow for dynamic quantification of tissue perfusion or therapy response after administration of an extracellular or target specific T_1 lowering contrast agent. Currently used T_1 mapping methods are based on Inversion Recovery (IR) approaches and the subsequent sampling of the recovery of the Mz magnetization [1]. Alternative methods use Spoiled Gradient Recalled-Echo (SPGR) methods [2] where T_1 can be extracted from a pair of SPGR images acquired at optimized flip angles [3]. These methods are limited by prolonged scan times, as they require the acquisition of several images and thus are sensitive to motion and not ideal for dynamic T_1 quantification of moving tissues such as the heart. In addition these approaches require post-processing for T_1 determination. In this work we present a new technique for fast T_1 estimation where the intensity of each pixel is linearly related to its T_1 value. The technique is based on a modified Quadruple Inversion Recovery (QIR) pre-pulse [4], which was developed for T_1 independent blood suppression. We hypothesize that two non-selective prepulses with optimized inversion times TI1 and TI2 and flip angles (Figure 1) will provide a linear relationship between Mz and the T_1 value of each pixel. In this work we present preliminary results in a T_1 phantom and in a preclinical in-vivo experiment.

METHODS

The novel fast T_1 map pre-pulse (fastT1-PP) (Figure 1) was implemented on a 3T Achieva Gyroscan MR scanner (Philips Healthcare, Best, NL). The longitudinal magnetization Mz in each pixel after application of the prepulse can be expressed by the follow equation (when $\theta_1=\theta_2=\pi$ we have the equation of the original implementation of QIR [4]).

$$\frac{Mz}{Mo} = [D \cdot A \cdot \cos\theta_1 \cdot \cos\theta_2 + (1-A) \cdot \cos\theta_2] \cdot C + (1-C)$$

Where: $A = \exp(-TI_1/T_1)$; $B = \exp(-(TR-TI_1)/T_1)$; $C = \exp(-TI_2/T_1)$; $D = \dfrac{1+B\cdot(\cos\theta_2-1)-A\cdot B\cdot\cos\theta_2}{1-A\cdot B\cdot\cos\theta_1\cdot\cos\theta_2}$

An optimization procedure was run in MATLAB (Mathworks, Natick, MA, USA) to find the optimal TI_1, TI_2, θ_1 and θ_2 that maximized the linear relationship between Mz and T_1. To take into account the proton density (PD) in each pixel, the rate of change in T_1 before and after contrast injection were calculated, which is independent of PD. Subsequently, the prepulse with optimized parameters was validated in a T_1 phantom and in a pre-clinical study of renal perfusion using a gadolinium based contrast agent. We compared our results with a T_1 sequence based on a Look-Locker technique [5].

RESULT

The simulation shows that several combinations of TR, TI_1, TI_2, θ_1 and θ_2 exist that allowed maximizing the linear relationship between Mz and T_1. Phantom results demonstrate an excellent linear relationship between pixel intensity and its T_1 value with a correlation coefficient of $R^2 > 0.97$ in the interval of T_1 between 200–1200 ms (Figure 2). Similar R^2 were obtained for a TR of 1000 and 2000 ms while a TR of 3000 ms resulted in a better linear correlation and also in a steeper slope and thus higher T_1 accuracy. A pilot in vivo study comparing the rate of change in T_1 in mouse renal parenchyma pre and 3 hours post a gadolinium based contrast agent shows no statistical difference between a conventional IR T1 mapping sequence and the fastT1-PP method (p=0.61) (Figure 3).

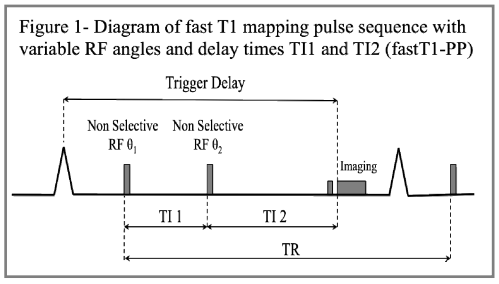

Figure 1- Diagram of fast T1 mapping pulse sequence with variable RF angles and delay times TI1 and TI2 (fastT1-PP)

CONCLUSIONS

We demonstrate a new approach for fast T_1 estimation, which only requires the acquisition of a single 2D or 3D dataset. Potential applications include T_1 quantification in myocardial perfusion imaging or T_1 estimation of myocardial fibrosis.

REFERENCES: [1] Look DC. Rev Sci Instrum 1970; [2] Christensen KA J Phys Chem 1974; [3] Deoni SCL MRM 2003; [4] Yarnykh V MRM 2002; [5] Blume U JMRI 2009

Figure 2- Phantom results of T_1 estimation using the fastT1-PP sequence. Signal intensities are plotted versus T_1 values for optimal combinations of $TI_1/TI_2/\theta_1/\theta_2$ for a TR of 1000, 2000 and 3000 ms.

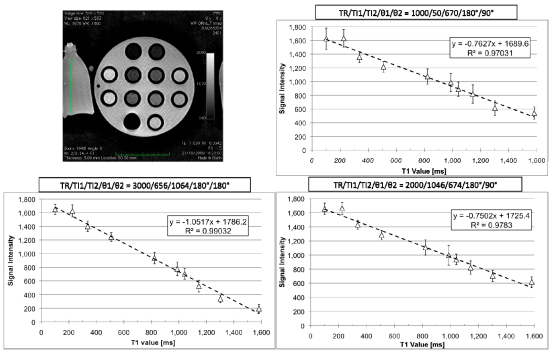

Figure 3- Rate of T_1 change in mice renal parenchyma after injection of a gadolinium based contrast agent. Comparison between Look-Locker based T1 mapping sequence and the novel fastT1-PP sequence.