## MRI signal delay: A potential probing mechanism for cellular imaging in the brain

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## INTRODUCTION

This work reports new observations in our recent ultrashort echo time (UTE) MRI experiments on human brain, in which MRI signal at an individual imaging voxel was delayed along TE direction and decayed as a multi-peak Gaussian-shaped curve instead of usually-observed exponential decay. We hypothesized that this signal delay was caused by an electromagnetic (EM) interaction between RF pulse and mobile ions from multiple cellular compartments in tissue such as intra- and extra-cellular spaces as well as cell membrane. This EM interaction may provide a new probing mechanism for non-invasively measuring parameters characterizing cellular microenvironment, such as ion concentration and T2\* relaxation time.

## **EXPERIMENTS**

Experiments were performed on a whole-body 3T scanner (Magnetom Trio Tim, Siemens Medical Solutions, Erlangen, Germany) with the Tim head coil. Adult healthy volunteers were scanned under an IRB approved protocol. A data acquisition for whole brain was implemented using a home-developed three-dimensional (3D) UTE pulse sequence (acquisition-weighted stack of spirals, AWSOS) (1), with parameters of sinc RF pulse (0.8ms in duration and 1.5 in cycle), flip angle= $30^{\circ}$ , TR=80ms, TE=0.6-40ms (11-steps), fat saturation on, FOV= $220 \times 220mm^2$ , 60 slices at thickness=2.5mm, matrix size= $256 \times 256$ , in-plane spirals=24 at readout time=7.84ms. The acquisition time was 1.92min per a TE. Manual shimming was used to achieve good shim (linewidth <25Hz). No corrections were used during gridding-based spiral image reconstruction. The delay time (T<sub>d</sub>) of FID signal at an individual pixel was manually measured by plotting out FID signal along TE direction in MATLAB (R2009a, The MathWorks, Inc., Natick, MA). A UTE-T2\* mapping, based on exponential decay, was also implemented using data at all the eleven TEs including the ultrashort TE (0.6ms).

## **RESULTS AND DISCUSSION**

Fig. 1 shows four typical shapes of the MRI signal decay selected from individual pixels in the image of a healthy subject brain (Fig. 2). Both regular (undelayed) and delayed signals were observed. All the delays happened at TE  $\leq$  10ms. Fig. 2 demonstrates the distribution of pixels with delayed MRI signal in the selected slice. Also included in Fig. 2 is a UTE-T2\* map. The signal delay in this healthy brain is small (T<sub>d</sub><5ms) in general, with scatted large delays (T<sub>d</sub>>5ms) inside the brain and with mean= 5.3ms, std=2.6ms, median=5.0ms. The number of pixels of delayed signal (T<sub>d</sub>>1ms) is 47% of total 4795 pixels examined. There is no visible correlation between distributions of the signal delay and UTE T2\*, indicating independency between them.

To explore the reason for the MRI signal delay, we **hypothesized** that 1) an electromagnetic (EM) interaction between RF pulse and mobile ions in tissue was responsible for the signal delay (i.e., the effect of micro eddy currents in tissue) and 2) the delay time was dependent on ion concentration. With



**Fig. 2.** MRI signal delay in a healthy human brain (right hemisphere): UTE image at 3T (left), signal delay map (middle), and UTE-T2\* map (right). Small delays (<5ms) are uniformly distributed in the brain with scatted large delays (>5ms). The delay is not correlated with T2\* time, an independent parameter.



these hypotheses, we came up with a three-compartment model consisting of intra- and extra-cellular spaces as well as cell membrane, to illuminate the observed decay curves in Fig. 1. First, the three compartments have distinct T2\* times (~1ms for cell membrane, ~3ms and ~40ms for intraand extra-cellular spaces, respectively), **separately locating** themselves in TE direction. Second, the three compartments have different ion concentrations, leading to variable delays to MRI signals (Fig. 1). Based on these two properties induced by the EM interaction, we expect that ion concentration and T2\* time may be measured from the delayed MRI signals for intra-/extra-cellular spaces and cell membrane, respectively. We are planning a series of experiments on these issues to verify our hypotheses.

**REFERENCES:** [1] Qian Y, etc. MRM 2008; 60:135-145.