Adiabatic $T_{1\rho}$ and $T_{2\rho}$ relaxation measurements of J-Coupled spins. Results from phantoms and from the human brain at 4T

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Introduction

Relaxation measurements of J-coupled systems are problematic due to the phase modulation which is superimposed on the relaxation decay. The J-evolution can be markedly reduced by manipulating pulse sequence architecture (1). For instance, the conventional Carr-Purcell-Meiboom-Gill (CPMG) pulse sequence practically eliminates J-evolution when the fast repetition limit is reached. The goal of the present work was to investigate the effect of J-evolution during time-dependent rotating frame relaxation measurements performed with adiabatic full passage pulses, for both strongly coupled and weakly coupled systems. Two configurations of fully adiabatic pulse sequences were used in phantom preparations and in humans. In the first configuration, a train of adiabatic full passage (AFP) pulses was placed prior to the coherent excitation by an adiabatic half passage (AHP) pulse. In this case, the relaxation is solely governed by $T_{1\rho}$, since magnetization is locked along the effective time-dependent frequency $\omega_{eff}(t)$ (2). In the second configuration, the train of AFP pulses was placed after the AHP. Therefore, magnetization is in the XY plane of the laboratory frame (LF) after the application of the excitation pulse, and undergoes inversion by the AFP pulses. In this case, the relaxation is solely $T_{2\rho}$. Based on the findings of this study, we concluded that the $T_{1\rho}$ experiment completely eliminates J-modulation of strongly and weakly coupled systems, while the $T_{2\rho}$ experiment significantly reduces J-evolution of strongly coupled systems as compared to conventional free precession T_2 relaxation experiment.

Methods

Measurements were performed on a 4T/90 cm magnet (Magnex Scientific, UK), interfaced to Varian INOVA console. Spectra were acquired from 2 phantoms preparations (see caption of Fig. 1 for details) and from the human brain. LASER was used for localization (echo time, TE= 39ms). Macromolecules (MM) contribution was minimized by MM-nulling using inversion recovery (inversion time, TI=0.18s). A train of hyperbolic secant AFP pulses (length=6ms; adiabaticity factor R=20; peak-power $\omega_1^{max}/(2\pi)$=1.3 kHz; phases prescribed according to MLEV-4,-8,-16,-32 with no interpulse time intervals) was placed before or after the coherent excitation by adiabatic half passage (AHP) pulse, leading to $T_{1\rho}$ or $T_{2\rho}$ relaxations, respectively (4). In the $T_{1\rho}$ or $T_{2\rho}$ experiments, the signal intensity decay time (TD) was the sum of the echo time (TE) identified by the LASER localization, plus the duration of the pulse train, where the number of AFP pulses was incremented from 4 to 32. In the free-precession configuration, no train of AFP pulses was applied before LASER localization. Therefore, in this case, the decay time was coincident with TE, which was increased by incrementing the interpulse time intervals between the six AFP used for localization.

Results and Discussion

Both phantom and *in vivo* results (Fig. 1) demonstrated that the decay of the signal intensity of J-modulated systems - as glutamate (Glu) or lactate (Lac) - are not affected by J-modulation in the $T_{1\rho}$ configuration, as opposite to the T_2 free precession. In the latter case J-coupled spins indeed undergo phase evolutions which generally complicate the analysis of *in vivo* spectra where resonances from several metabolites overlap. Regarding the $T_{2\rho}$, this was found to significantly reduce the J-evolution of Glu (strongly coupled system) but not significantly for Lac (weakly coupled system). The absence of the phase modulation due to J-evolution is useful because it notably simplifies quantification of relaxation measurements also for resonances other than singlets. The estimation of relaxation rates during adiabatic pulses can in turn provide quantitative information on the dynamics of metabolites, something that is generally not accessible through conventional ^{1}H-MRS. Therefore, the results of the present study imply that quantitative analysis of the dynamics of metabolites through adiabatic relaxation measurements are feasible also for those compounds which are affected by J-evolutions. This possibility advances conventional ^{1}H spectroscopic NMR techniques to investigate the spin dynamic of metabolites (as glutamate, for instance) which are of notable interest for addressing neuroscience-related issues.

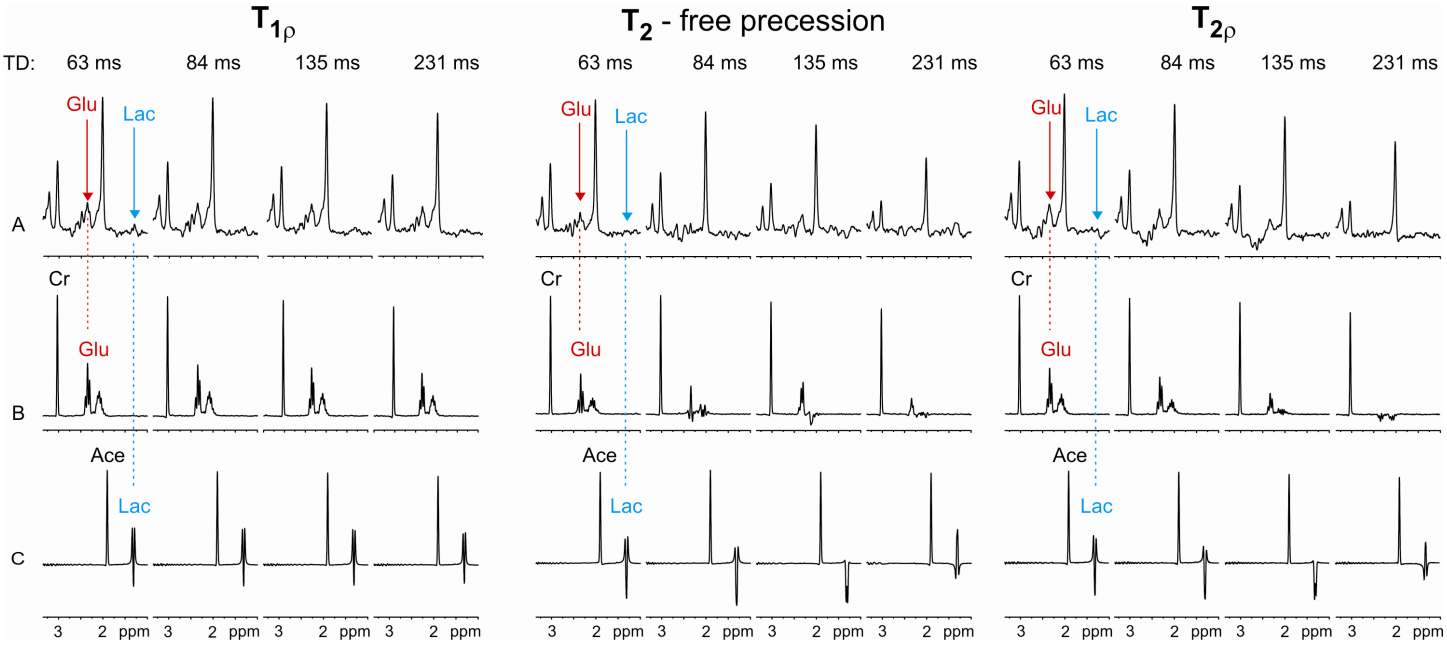

Figure 1: Effect of J-evolution in $T_{1\rho}$, T_2 free-precession, and $T_{2\rho}$ experiments. A) *In vivo* spectra acquired from 8ml voxel localized in the human visual cortex, # scans = 16, TR=5s. B) Spectra from a phantom containing 50 mM creatine (Cr) and 50 mM Glu, pH=7.1; # scans=8, TR=5s. C) Spectra from a phantom containing 100 mM acetate (Ace) and 100 mM lactate (Lac), pH=7.1, # scans=8, TR=5s. Ace and Cr where utilized in the phantom preparations as a reference for phasing. TD indicates the signal intensity decay time.

References: 1.Kupce et al, JMR 2007;187:258. 2. Michaeli et al, JMR 2006;181:138. 3. Michaeli S et al. JMR 2004;169:293. 4. Michaeli et al, Current Analytical Chemistry 2007;in press.
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