Experimental Validation of a T2r Transverse Relaxation Model using LASER and CPMG Acquisitions

S. Nikolova[1], R. Bartha[1], C. Bowen[2]

[1]Robarts Research Institute, London, On, Canada, [2]Institute for Biodiagnostics (Atlantic), Halifax, Nova Scotia, Canada

Introduction: The LASER MR multi-echo spin-echo pulse sequence (1) has shown promise in detecting tissue changes within the first few minute of ischemia and has been investigated as a novel source of tissue contrast in ischemic injury (2). LASER apparent transverse relaxation rate ($R_2^\dagger = 1/T_2^\dagger$) is dependent on the time between spin echo refocusing pulses ($2\tau_{cp}$), which limits the time for spins to diffuse through tissue regions with different magnetic susceptibility, and $R_{2\rho}$ relaxation that occurs during the adiabatic pulses (3). The purpose of this study was to investigate the contribution of magnetic susceptibility to $R_2^\dagger$ measured by LASER while controlling the effects of diffusion, and to compare it to $R_2^\dagger$ measured using a conventional CPMG pulse sequence. ORGASOL® polyamide powders were used to generate three phantoms with different magnetic susceptibility.

Methods: Experiments were performed using a whole body Oxford Magnet Technology (OMT) 90cm 4T magnet, Varian Unity INOVA console, and Siemens Sonata gradient system. Phantoms were designed to produce a range of $R_2^\dagger$ measurable by the LASER pulse sequence. Phantoms were created in 50 ml cylindrical flasks containing a 10% volume fraction (v) of ORGASOL® (polyamide powder, density 1.07g/L), 5% agarose gel, 100mM NaCl, and 33% photoflo used as a surfactant. Phantom 1 contained 10 μm ORGASOL + 1 mM Gd-DTPA, Phantom 2: 10 μm ORGASOL + 1.5 mM Gd-DTPA, Phantom 3: 10 μm ORGASOL + 2 mM Gd-DTPA. Data were collected from each phantom to measure $R_2^\dagger$ as a function of τ_{cp} (2.4 - 6.1 ms). The MR signal decay in LASER was sampled at seven different echo times by inserting 0, 4, 8, 12, 16, 20 or 24 non-selective refocusing pulses (HS2-R10) before the six slice selective LASER pulses (HS2-R15) while keeping τ_{cp} constant. For CPMG, 16 different echo times were sampled spanning a similar range to that of LASER. The rate of signal decay (R_2) in both cases was determined by linear regression of spectral peak height as a function of echo time. The variation of R_2 as a function of τ_{cp} obtained with CPMG was fit using Chemical Exchange (CE) theory (Eq.1,(4)) varying τ_{ex}, R_{20}, R_{2D}. Fit values for these parameters were compared to theoretical values obtained with Eq.1.
Experimental $R_2^\dagger$ differences were used to estimate $R_{2\rho}$ at low τ_{cp} using Eq.2,(3) and compared against the expected change due to susceptibility (Eq.3,2).

Results: Fig. 1 compares experimental apparent R_2 values with CE theory for Phantom 1.**Fig.2** shows the variation in $R_{2\rho}$ as a function of susceptibility. The slope of the linear regression (0.00518) agreed with the expected change (0.00527) based on theoretical calculations (Eqs.2and3,(3)).

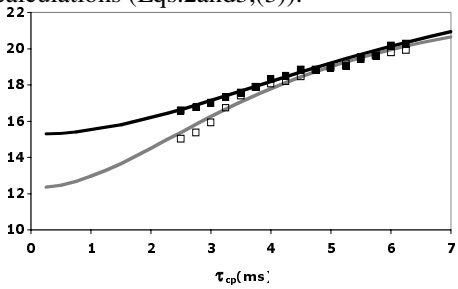

Fig 1. Experimental R_2 data (points) and Luz Meiboom CE theory (solid line) for Phantom #1 LASER (black), CPMG (gray).

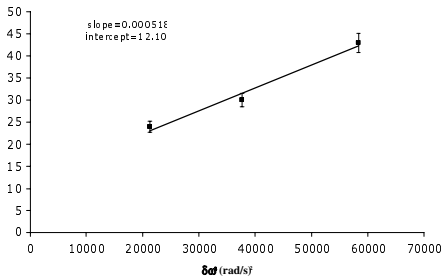

Fig 2. $R_{2\rho}$ estimates obtained from all three phantoms plotted as a function of susceptibility. The slope of the line indicates $R_{2\rho,ex}$ and the intercept- indicates $R_{2\rho,dd}$ (Eq.[3]).

$$R_{20} + 5.17 \times 10^{9} \frac{v}{D} r_0^2 [Gd]^2 \left\{ 1 - \frac{\tau_{ex}}{\tau_{cp}} \tanh \frac{\tau_{cp}}{\tau_{ex}} \right\} \quad [$$

$$R_2^+ = \{R_{2\rho} - R_2\} \frac{T_p}{2\tau_{cp}} + R_2 \quad [2]$$

$$R_{2\rho} = \frac{1}{T_p} \int_0^{T} R_{2\rho,ex}(t)dt + \frac{1}{T_p} \int_0^{T} R_{2\rho,dd}(t)dt \quad [3$$

$R_{2\rho,ex}$ = rate constant due to exchan
$R_{2\rho,dd}$ = due to dipolar interaction
T_p = pulse duration

Discussion: Phantoms were successfully created using polyamide microspheres to study the effect of microscopic susceptibility on LASER signal intensity. Measured variations in relaxation rates (R_2) with CPMG were consistent with the predictions of the Luz-Meiboom two-site chemical exchange theory. Differences in $R_2^\dagger$ were observed with LASER at low τ_{cp} demonstrating increased sensitivity to microscopic susceptibility and were explained by $R_{2\rho}$ relaxation during the adiabatic pulses.

Acknowledgements and References: The Authors wish to thank Dr. Michael Garwood for providing the original LASER spectroscopy sequence. Funding provided by the Robarts Research Institute, Canadian Institutes of Health Research (MME-15594), and National Institute of Health Research (R01-EB001852). (1) Garwood and DelaBarre. J Magn Reson 2001; 153: 155-177.(2) Nikolova et al. MRM2005, in press. (3) Michaeli et al. MRM 2005; 53:823-829 (4) Brooks and Gillis, MRM 2001:45:1014-1020.