In-vivo T_1 and T_2* tissue-relaxation rates of H_2O^{17} at 16.4 Tesla

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Motivation

The measurement of cerebral metabolic rate of oxygen ($CMRO_2$) via direct NMR detection of the stable oxygen isotope O^{17} is a promising tool to study alterations in brain activity and pathology. Due to the low natural abundance of 0.037% H_2O^{17}, optimized acquisition parameters are crucial for O^{17}-weigthed MRI of metabolically produced cerebral water. It has been suggested that signal-to-noise ratio increases almost quadratically with B_0 due to field-independent quadrupolar interactions of O^{17} [Zhu2001, Thelwall2003]. Thus, in comparison to studies at lower field strengths the increased magnetization available at 16.4 T allows an enhanced spatial resolution and thus for the first time a tissue-specific determination of O^{17} relaxation.

Methods

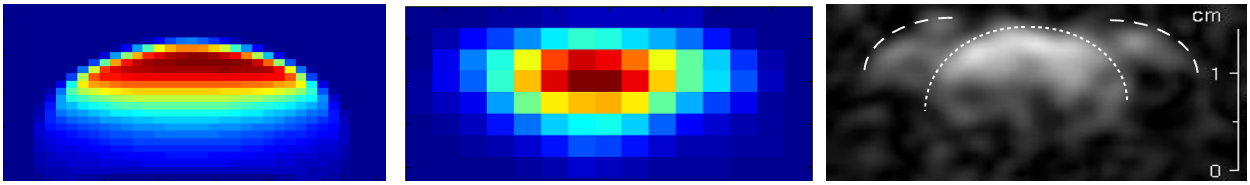
In-vitro & in-vivo images were acquired with (inversion recovery-)CSI or FLASH sequences on a 16.4 Tesla, Ø 26 cm bore (Magnex) magnet interfaced to a Bruker console with a one turn Ø 4 mm silver wire surface-coil (Ø 2 cm). All images were acquired with a Field-of-View of 3.5 x 3.5 x 2.5 cm^3.

In-vitro: 20 g water-phantom with enriched 10% H_2O^{17} in a glass cylinder. All images were acquired with CSI.

In-vivo: 2 self-breathing Isoflurane anesthetized male Wistar rats (500 g) were examined. Ventilation gases were continuously monitored and body temperature was maintained at 37 +/-0.3 °C with an electric heat blanket.

Two types of images were sequentially acquired: 1. High-resolution CSI (Matrix 39x39x7) & 3D-FLASH (32x32x8) for anatomical identification of muscle, cortex and deep brain tissue. 2. CSI with a high number of signal averages for T_1 (inversion with block-pulses; 8 different inversion times (TI) 3-50 ms; Matrix 15x15x7) and T_2*-relaxation (based on FIDs in image space; Matrix 17x17x7). Weighted-CSI sequence parameters for the T_1-relaxation measurements: RF 50 µs, phase-encode 424 µs, TI 3-50 ms, TR 65 ms, spectral acquisition points 94, SW 9.4 kHz, total acquired FIDs 51200 (339 Averages); Parameters for T_2*-relaxation: RF 50 µs, phase-encode 424 µs, TR 6.45 ms, spectral acquisition points 260, SW 52 kHz, total acquired FIDs 524488 (2158 Averages).

Results



In-vitro CSI 10% H_2O^{17} Phantom (left); In-vivo IR-CSI (middle) & FLASH (right) of natural abundance H_2O^{17} in the rat

T_1 [ms]	in-vitro 6.93 +/- 0.34	in-vivo 6.53 +/- 0.15 (77 µl deep brain tissue)		
T_2* (ms)	in-vitro 2.24 +/- 0.09	1.39 +/- 0.14 (75 µl muscle tissue)	1.83 +/- 0.20 (92 µl surface cortex)	2.08 +/- 0.23 (75 µl deep brain tissue)

It is shown that T_2* values in different tissue types vary. All relaxation rates showed mono-exponential behavior.

Conclusions

Significant difference in T_2* of muscle tissue in comparison to cortex tissue was determined, possibly resulting from lower diffusion of water molecules in muscles or from different biochemical environment. Low T_2* relaxation rates of muscle tissue might be beneficial reducing partial-volume contaminations if read-out and TR is optimized for cortex H_2O^{17}. The T_1/T_2* values determined can be used to tune parameters (e.g. Ernst angle, read-out duration, TR) to maximize SNR per unit time, as required in functional $CMRO_2$ measurements by short inhalations of O_2^{17} gas.

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References: Thelwall et. al. Proceedings of the ISMRM 2003, Zhu et. al. Magnetic Resonance in Medicine 2001