^{1}H decoupled ^{13}C MRS in human muscle at 7T

D. E. Befroy[1], P. B. Brown[1], K. F. Petersen[1], G. I. Shulman[1], and D. L. Rothman[1]
[1]Yale University, New Haven, CT, United States

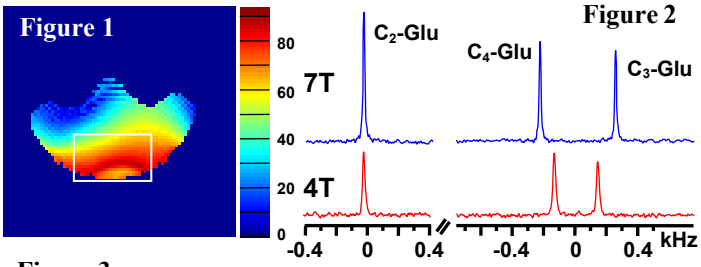
Introduction

The development of wide-bore, high-field (>4T) MR systems can potentially enhance in-vivo human MRS due to the increase in signal/noise (S/N) and spectral dispersion with the B_0 field strength. For J-coupled metabolites this enhancement is mitigated; RF power requirements also increase with the B_0 field-strength and the application of conventional decoupling schemes for ^{13}C-MRS in the brain or torso is prohibited by the need to maintain the pulse sequence within SAR guidelines. However, the SAR limit for peripheral tissues is significantly higher than for brain/torso, and by restricting the region of interest (ROI) to a superficial muscle group such that efficient, small diameter coils can be used for signal excitation, we hypothesized that ^{1}H decoupling within the SAR limit (12W/kg) would be possible. In this study, we demonstrate that the acquisition of ^{1}H-decoupled ^{13}C spectra in human muscle is feasible at 7T, and offers a significant improvement in spectral quality versus 4T.

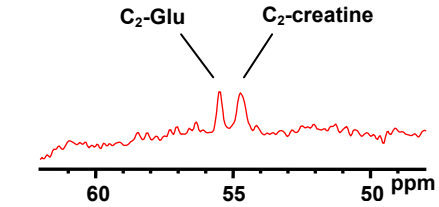
Methods

A custom-built probe for ^{13}C-MRS at 7T was fabricated consisting of a 5cm diameter ^{13}C surface coil, with a pair of elliptical 9.5 x 7.5cm ^{1}H coils arrayed in quadrature for decoupling; experiments were performed on a Varian Inova system. Comparison experiments at 4T were performed on a Bruker Medspec system, using a probe with equivalent coil dimensions: a 5 x 4 cm elliptical ^{13}C surface coil, elliptical 10 x 7cm quadrature ^{1}H coils. To determine the uniformity of the decoupling field, B_1 field maps for ^{1}H were obtained using a gradient-echo imaging sequence at 2 different flip angles (θ and 2θ). ^{13}C spectra were acquired on each system using a custom-written adiabatic ^{13}C-[^{1}H] polarization-transfer (PT) sequence with WALTZ16 decoupling. PT echo-times and transmitter offsets were optimized independently to detect C_2 or C_4-glutamate. Peak ^{13}C and ^{1}H RF power at the inputs of the probe were measured with an oscilloscope; average RF power and SAR over the duty-cycle of the PT sequence were calculated in Matlab.

Results

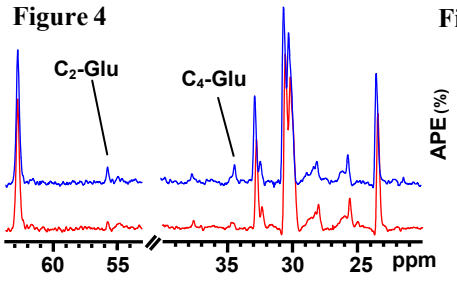


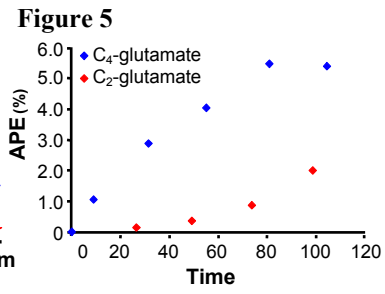
B_1 field maps obtained from a phantom demonstrated that the ^{1}H coil geometry of the 7T probe generated a relatively homogeneous B_1 field (Figure 1) in the region of the calf from which ^{13}C signal is acquired and indicated that decoupling would not cause focal tissue heating. ^{1}H decoupling with a bandwidth of ~1.7 kHz - sufficient to decouple the majority of ^{13}C metabolites at 7T - was achieved at 106W over an acquisition-time of 68 msec. PT spectra acquired at 4T and 7T from a 100mM glutamate phantom under identical conditions (T_R = 5sec, #scans = 128) demonstrated an enhancement in S/N of ~70% for C_4-glutamate and ~100% for C_2-glutamate at 7T (Figure 2); estimated SAR (4.25 W/kg) was well within FDA limits.



For in-vivo glutamate detection, we therefore reduced the T_R to 2.8sec and incorporated 1D-ISIS localization to select a region of muscle adjacent to the ^{13}C surface coil and minimize lipid contamination from subcutaneous fat. A 36 minute natural-abundance spectrum of C_2-glutamate acquired from the medial gastrocnemius muscle is shown in Figure 3; under these conditions SAR = 7.55 W/kg.

To complete these preliminary studies, we obtained timecourses of muscle C_4 and C_2-glutamate enrichment during a 2 hour infusion of 2-^{13}C labeled acetate by interleaving optimized acquisition conditions in ~5min blocks. For detection of C_4-glutamate, residual lipid signal due to IMCL was suppressed with a T_1-based inversion-null lipid suppression module prior to localization and excitation (SAR = 7.79W/kg). Enrichment in both positions of glutamate due to oxidation via the TCA cycle was observed. Baseline and end of infusion spectra are shown in Figure 4 and timecourses of enrichment in Figure 5.





Conclusion

By taking advantage of the higher SAR limits for peripheral tissues, and by restricting the ROI to a superficial muscle group such that relatively small RF coils can be used for signal excitation/detection, we have demonstrated that ^{1}H-decoupled ^{13}C spectroscopy of human muscle is feasible at 7T. S/N of ^{13}C metabolites is significantly enhanced compared to an equivalent technique at 4T.