Implementing Cerebral ^{13}C MRS Using Low RF Power for Proton Decoupling on a 3 Tesla Clinical Scanner

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Introduction

[1-^{13}C]glucose is commonly used in ^{13}C MRS of human brain. It was shown recently that there are important advantages using [2-^{13}C]glucose instead (1). The kinetics of ^{13}C label incorporation from [2-^{13}C]glucose into glutamate C5, glutamine C5 and GABA C1 are identical to those from [1-^{13}C]glucose into glutamate C4, glutamine C4 and GABA C2, respectively. Because the carboxylic and amide carbons are broadened by very weak long-range ^{1}H-^{13}C couplings, broadband decoupling can be achieved using noise pulses with very low RF power (1). In addition, contamination from subcutaneous lipid signals is no longer an issue because lipids do not resonate in the vicinity of glutamate C5, glutamine C5 or GABA C1. Here we describe implementation of this approach for human studies using a standard 3 Tesla GE scanner. A manufacturer-provided standalone decoupler which can only output a bi-level hard-wired WALTZ-4 pulse train was also used.

An in vivo cerebral ^{13}C spectrum of the carboxylic/amide carbon region acquired at 4.7 Tesla from a rhesus monkey infused with [2-^{13}C]glucose is given in Fig. 1. It was acquired with $<\gamma B_2>$ = 360 Hz and 20 min signal averaging. LB = -4 and GB = 0.3. As shown in Fig. 1, for studying the glutamate-glutamine cycle in the human brain at 3 Tesla, it is important to resolve glutamine C5 from aspartate C4. Glutamine C5 is broadened not only by the methylene protons but also by the zusammen amide proton resonating at 6.83 ppm.

Method

Phantom experiments were performed on a standard GE 3 Tesla MRI scanner (Signa). The standalone proton decoupler, TR switch, ^{13}C preamp and filters provided by GE were used. The proton decoupler outputs a bi-level WALTZ-4 pulse train triggered by TTL signals from the MRI scanner: low level pulsing during relaxation period for generating NOE enhancement and high level pulsing during ^{13}C data acquisition for proton decoupling. The standalone decoupler is interfaced to a 1 kW RF amplifier. A single-loop ^{13}C surface coil (dia. = 7 cm) and a quadrature proton surface coil mounted on a half cylindrical tube (dia. = 20 cm) were constructed. The phantom was a 2000 ml cylindrical water bottle (dia. = 12 cm) containing a sphere (dia. = 7 cm) filled with a solution of 250 mM glutamine and 250 mM aspartate (pH = 7.02). The water bottle loads approximately the same as an adult human head. A pulse-and-acquire sequence provided by GE was used for scanning. The ^{13}C pulse angle was set to 30-40^{o}. SW = 5 kHz. Number of data points = 2048. NS = 128. Recycle delay = 2.0 s. The nominal 90^{o} pulse width for WALTZ-4 was set to 1.6 ms (γB_2 = 156 Hz, decoupler forward power = 12 W, level 1) and 2.0 ms (γB_2 = 125 Hz, decoupler forward power = 8 W, level 2), respectively, both are lower than all previously published decoupling power settings for human brain ^{13}C MRS studies. The hard-wired NOE RF power control was disabled so as to fix the forward power for NOE at 1 W regardless of the power setting used for proton decoupling.

Results and Discussion

Fig. 2a shows the phantom spectrum obtained using level 1 WALTZ-4 decoupling. LB = -4 and GB = 0.3. Glutamine C5 and aspartate C4 resonances were clearly resolved. The SNR achieved for the 4.5–min spectrum of 2.75 mM natural abundance ^{13}C labels was also sufficient for in vivo applications. Spectrum 2b was acquired using level 2 WALTZ-4 decoupling. The spectral separation between glutamine C5 and aspartate C4 is less than in Fig. 2a. The T_1 of nonprotonated glutamate, glutamine and GABA carboxylic/amide carbons are significantly longer than that of the protonated methylene carbons. Therefore, small flip angle (< 90^{o}) and relatively long TR (> 2 sec used here) will be needed for optimal SNR. Furthermore, although the maximum NOE enhancement is not dependent on the distance between ^{13}C and nearby protons, the rate of NOE buildup is. Therefore, for the carboxylic/amide carbons, longer TR should also allow higher NOE enhancement. Clearly, TR and flip angle can be further optimized to increase the SNR of this method. Further reduction of SAR can also be achieved by increasing TR.

References

(1) S. Li, et al, In: Abstracts of ESMRMB 2006, p 52.