In Vivo ^{13}C MRS Using Very Low RF Power for Proton Decoupling

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Introduction

One of the major difficulties of in vivo ^{13}C MRS with infusion of [1-^{13}C]glucose has been the necessity to decouple the large, one-bond, ^{1}H-^{13}C scalar couplings ($^{1}J_{CH}$ = 125-145 Hz). The decoupling pulse strength (γB_2) has to be significantly greater than $^{1}J_{CH}$. The RF deposition at 1.5-4.0 Tesla systems is often close to the FDA safety limits. As the result, in vivo ^{13}C MRS studies have been limited to the occipital lobe of human brain. Here we test a novel strategy for in vivo cerebral ^{13}C MRS using rhesus monkeys. It is realized that the turnover kinetics of [5-^{13}C]glutamate from exogenous [2-^{13}C]glucose is identical to that of [4-^{13}C]glutamate from exogenous [1-^{13}C]glucose. With the infusion of [2-^{13}C]glucose, the carboxylic/amide carbons are only coupled to protons via very weak long-range ^{1}H-^{13}C scalar couplings. Thus, they can be effectively decoupled at very low RF power. Because of the lack of lipid signals in the vicinity of the [5-^{13}C]glutamate and [5-^{13}C]glutamine peaks, interference from subcutaneous lipids is no longer a problem.

Method

In vivo experiments were performed on a 4.7 T Bruker with a 30-cm i.d. gradient coil. A 5 cm ^{13}C surface coil and a double-D linear ^{1}H coil were used. Two female rhesus monkeys (5~6 kg) were examined. Administration of [2-^{13}C]D-glucose (99% enrichment, 20% w/w) began with a 12 ml bolus injection followed by IV infusion to maintain an average concentration of 17 ± 2 mM. The pulse sequence is shown in Fig. 1a. NOE was generated using a train of nominal 180^{o} ^{1}H pulses spaced 200 ms (Δ) apart. All spectra were acquired with a 30-40^{o} ^{13}C pulse, SW = 10 kHz, Acq. = 204 ms, and TR = 2.3 s.

Three decoupling pulse sequences were examined. Fig 1b shows the Ernst pseudo noise pulse (1): constant amplitude and phase randomly assigned to either 0^{o} or 180^{o}. It has a 1 ms repetition unit and a nominal γB_2 of 100 Hz. Fig 1c shows the vectorial noise pulse: random amplitude and random phase (0^{o}-360^{o}). It has 1 ms repetition unit and a nominal maximum γB_2 of 173 Hz. The average $(\gamma B_2)^2$ of the vectorial noise pulse is the same as that of the pseudo noise pulse with γB_2 = 100 Hz. The WALTZ-4 pulse with γB_2 = 100 Hz (i.e., 2.5 ms for a nominal 90^{o} pulse unit) was also evaluated. The decoupler forward power was approximately 0.9 W using the constant amplitude decoupling pulses, which corresponds to a time-averaged forward decoupling power of 0.08 W.

Results

Fig. 2 shows the time course spectra using the Ernst pseudo noise decoupling pulse with γB_2 = 100 Hz. Each spectrum is an average of 512 scans**.** As shown in Fig. 2, glutamate C5 and C1, glutamine C5 and C1, aspartate C4 and C1, N-acetylaspartate C5, C4 and C1, GABA C1, and bicarbonate were detected. Fig. 3 shows comparable time course spectra acquired using the vectorial noise decoupling pulse with a nominal maximum γB_2 of 173 Hz . Fig. 4 shows a comparison of an undecoupled spectrum (lower trace) with that decoupled by WALTZ-4 with a nominal maximum γB_2 of 100 Hz. Each spectrum was accumulated for 20 min. The WALTZ-4 pulse only has negligible decoupling effect at the low power level used in this study. At high RF power, all three decoupling sequences produced equivalent results with unambiguous spectral resolution.

In summary, detection of the dynamic turnover of ^{13}C label incorporation into glutamate C5, glutamine C5 and GABA C1 from infused [2-^{13}C]glucose offers a solution to overcome one of the main obstacles to wider applications of in vivo ^{13}C MRS. Application of this new strategy to in vivo ^{13}C MRS of human frontal lobe is currently in progress.

Reference

(1) R Ernst, J Chem Phys 1966;45:3845.