In Vivo Single-Shot, Localized ^{13}C Spectroscopy of Rhesus Monkey Brain at 4.7T

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INTRODUCTION

Carbon-13 MR spectroscopy is a powerful method for measurement of metabolism of the living brain. In this study, we present a single-shot 3D localized, polarization transfer ^{13}C spectroscopy method and apply it to rhesus monkey brains at 4.7T. Both natural abundance and ^{13}C-enriched spectra have been acquired. The results show excellent SNR and spectral resolution.

METHOD

The experiments were performed on a Bruker spectrometer interfaced to a 4.7T 30-cm horizontal bore magnet. A ^{13}C surface coil (Dia.=6cm) was placed inside a double-D linear ^{1}H coil formed on the surface of a 12-cm diameter cylindrical tube. The coils were attached to a home built stereotaxic device for the monkey head (Fig. 1). Two female rhesus monkeys (~6kg) were examined. They were placed in prone position and anesthetized with a mixture of ketamine (0.1 mg/kg) and dormitor (0.02mg/kg) through hourly intramuscular injection. Administration of 20% water solution of 99% [1-^{13}C] glucose began with a 12 ml bolus injection followed by IV infusion to maintain glucose concentration at ~15mM. Monkey body temperature was maintained at 37 ± 0.5^{o}C during the scans.

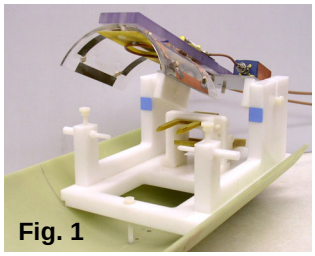
The pulse sequence was constructed based on INEPT where RF pulses in polarization transfer were used for 3D localization through proton. All RF pulses were adiabatic except two 90^{o} pulses. Details of the sequence design principle and the characteristics of adiabatic pulses have been described previously (1). As shown in Fig. 2, additional adiabatic pulses have been added to refocus the antiphase polarization transferred ^{1}H-^{13}C magnetization. In Fig. 2, blue-colored pulses are adiabatic half-passage (AHP) pulses, red-colored ones are adiabatic full-passage (AFP) pulses and green-colored ones are sinc3 pulses. β=1/4J. τ=1/8J (for CH_2). The voxel size was 3.5x2.5x3.5 cm^3 (30ml) (Fig. 3). No additional OVS pulses were found necessary. Spectra of nature abundance myo-inositol in the monkey brain were acquired with 900 averages in 30 minutes. For the [1-^{13}C] glucose infusion experiments, multi-spectra were consecutively collected. Each of them had 300 averages accumulated over ~11 minutes. The entire time course study lasted ~2.5 hours.

RESULTS

A ^{13}C spectrum of natural abundance myo-inositol in monkey brain (sum of three 30-minute scans) is shown in Fig. 4. 4 Hz exponential line broadening was applied. Figure 5 shows an 11-min spectrum (LB=4Hz) acquired 2 hours after the start of glucose infusion. Twelve resonance peaks are clearly observed and assigned in the legend. For the time course study, six out of 16 consecutive spectra (11-minutes temporal resolution, LB=6Hz) are plotted in Fig. 6 which shows the turnover of glutamate, glutamine, and aspartate.

DISCUSSION

We have shown the localized ^{13}C spectra with excellent spectral and temporal resolution and SNR using a novel, single-shot, proton-localized, mostly adiabatic, polarization transfer technique. Our detection sensitivity of natural abundance myo-inositol (30 ml, 90 minutes) compares favorably with a previously result obtained at 2 Tesla from the human brain (144ml, 90 minutes) (2). In Fig. 5, the homonuclear ^{13}C-^{13}C couplings were well-resolved. The spectral resolution achieved here also compares favorably with previously published spectra acquired from human brain at 4 Tesla (3). The temporal and spectral resolution achieved in this study should allow simultaneous measurement of the turnover kinetics of glutamate, glutamine and aspartate from intravenously infused [1-^{13}C] glucose after pharmaceutical treatment.



REFERENCES

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