^{13}C Signal Enhancement in Human Brain at 7T by NOE and Stochastic Proton Decoupling

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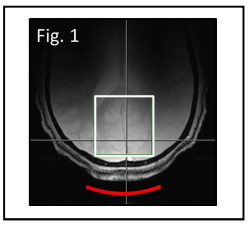
Target audience

Scientists and clinicians who are interested in heteronuclear MRS at high magnetic fields.

Purpose

Strong RF irradiation for NOE and proton decoupling have been major obstacles to performing traditional in vivo ^{13}C MRS of human brain at 7T (1, 2). To avoid excessive RF deposition, ^{13}C MRS without proton decoupling at 9.4T has been proposed (3). Recently, ^{13}C MRS in human brain with very low decoupling power has been performed at 3T (4) and 7T (5) by detecting carboxylic/amide carbons and using stochastic decoupling waveforms (6). Because the interactions between carboxylic/amide carbons and protons are much weaker as compared with alkyl carbons (3), the signal enhancement from NOE and proton decoupling may not be fully realizable, particularly at high fields where magnetic field inhomogeneity is much worse. This study is to evaluate how much the ^{13}C signals in phantom and human brain can be enhanced by NOE and proton decoupling at 7T.

Methods



Hardware: A Siemens 7T scanner with VB17 software was used. Proton coil was a shielded quadrature half-volume coil (two overlapping octagon loops, nominal size=12.7x12.7cm^2). ^{13}C coil was a surface coil (diameter=7.5cm), as indicated by the red line in Fig. 1. The coils were connected to the scanner via an interface box (Quality Electrodynamics) containing T/R switches, preamplifiers and filters for both channels.

Glucose infusion: Two antecubital veins of adult healthy subjects were cannulated, one for infusing [2-^{13}C]D-glucose (20% w/w) and the other for withdrawing blood to monitor glucose levels. The infusion started with a bolus infusion rate of 900ml/h followed by an exponential decay to the rate of 100ml/h at the 15th minute of infusion. The subsequent infusion rate was adjusted to keep glucose levels at 160-200mg/dL.

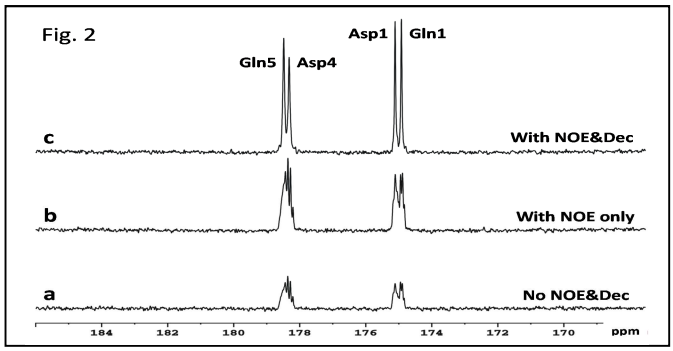
^{13}C MRS: A 6x6x6cm^3 voxel in the occipital lobe (white box in Fig. 1) was shimmed. The typical water linewidth from the voxel was ~14Hz. ^{13}C spectra were acquired using an excite-acquire sequence: hard pulse width =500μs, TR=5s, and SW=5kHz. ^{13}C flip angle was empirically optimized to obtain maximum SNR for a given TR. A train of 26 equally spaced hard pulses (pulse width=0.5ms, flip angle=180^o) were applied in proton channel during relaxation time for NOE. Stochastic waveforms were used during data acquisition for proton decoupling. The duration of each stochastic repeat unit was 0.5ms and γB_2=200Hz. All proton pulses were centered at the water signal. The average power in proton channel was 3.6 W. Acquisition of ^{13}C spectra from healthy volunteers (n=2) started at 60 min after [2-^{13}C]D-glucose infusion began.^{13}C MRS was also performed on a phantom of 3-liter water bottle with 6g NaCl. A 7-cm sphere filled with 200mM natural abundance glutamine (Gln) and aspartate (Asp) (pH=7.0) was placed at the bottom of the bottle.

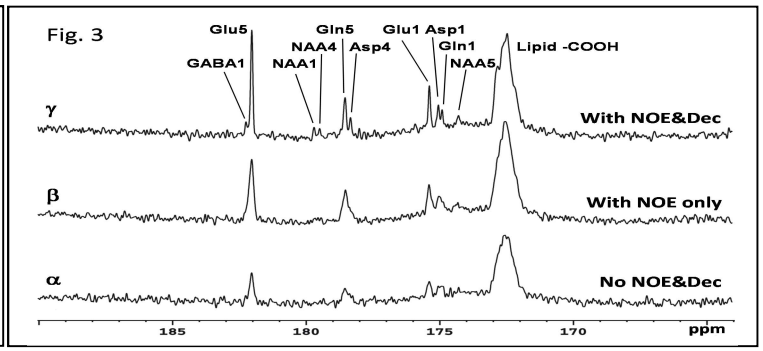
Results

An axial gradient-echo image (Fig. 1) demonstrates that the proton coil offers adequate B_1 field homogeneity for NOE and decoupling within the effective volume of the ^{13}C coil. Fig. 2 shows natural abundance ^{13}C spectra of the phantom (TR=5s, NA=104, data=2048, LB=1Hz) with neither NOE nor decoupling (a), with NOE only (b), and with NOE and decoupling (c). Well resolved peaks of Gln C5 and C1 as well as Asp C4 and C1 were detected in Fig. 2(c). Referenced with the Asp C1 peak amplitude (175.1ppm) in spectrum a, the Asp C1 peak amplitude in spectrum b and c was increased by a factor of 2.3 and 5.3, respectively. Fig. 3 shows the spectra from one of the healthy volunteers (TR=5s, NA=104, data=1024, LB=-3Hz, GB=0.2) with neither NOE nor decoupling (α), with NOE only (β) and with NOE and decoupling (γ). Resonance peaks of γ-aminobutyric acid (GABA) C1, glutamate (Glu) C5 and C1, Gln C5 and C1, Asp C4 and C1, as well as N-acetylaspartate C1, C4 and C5 were detected. For the in vivo spectra, the peak amplitude of Glu C5 (182.0ppm) was used to evaluate signal enhancement from NOE and decoupling. The peak amplitude of Glu C5 was increased, averaged over the two subjects, by a factor of 2.3 and 4.2 when only NOE was on and when both NOE and decoupling were on, respectively.

Discussion

The phantom and in vivo data have shown that the peak height of ^{13}C resonances can be increased more than twice by NOE pulses alone. However, SNR and spectral resolutions were still poor. The adjacent peaks less than 0.3 ppm apart could not be resolved without decoupling. With broad band and low power stochastic decoupling, ^{13}C signal height was boosted more than 5 and 4 times in the phantom and the human brain, respectively. The higher signal gain in phantom was attributed to a better shim condition than in the human brain. With the decoupling, adjacent peaks with 0.2-0.3 ppm apart can be well resolved. In conclusion, it is essential to applied NOE and broad band and low power proton decoupling when performing carboxylic/amide ^{13}C MRS at 7T.





References

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