

¹³C MRS of Human Brain at 7T Using Low Power Stochastic Proton Decoupling

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Target audience

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

Purpose

In conventional ¹³C MRS of human brain strong proton irradiation has been used to decouple large ¹H-¹³C scalar couplings (¹J_{CH}=125-145 Hz) for alkyl carbons of major brain metabolites¹. Excessive RF power deposition is one of the major obstacles to applying ¹³C MRS to human brain at 7T. Since carboxylic/amide carbons are only coupled to protons via weak long-range ¹H-¹³C scalar couplings they can be decoupled at very low RF power level with stochastic waveforms²⁻⁵. This study is to explore the feasibility of measuring carboxylic/amide carbons in occipital lobe of human brain at 7T using low RF power stochastic decoupling.

Methods

Hardware: A Siemens 7T scanner with VB17 software was used for the study. Proton coil was a shielded quadrature half-volume coil (two overlapping octagon loops, width = 12.7 cm). The coil and slotted RF shield were placed on two semicylindrical tubes with outer diameter of 20.3 cm and 22.8 cm, respectively. A single loop ¹³C coil (diameter= 7.5 cm) was used for ¹³C excitation and signal detection as indicated by the red line in Fig. 1. The coils were connected to the scanner via an RF interface box (Quality Electrodynamics) containing T/R switches, preamplifiers and filters for both channels.

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

¹³C MRS: A 5x5x5 cm³ voxel in the occipital lobe (white box in Fig. 1) was shimmed. The typical water linewidth from the cubical voxel was ~14 Hz. ¹³C spectra were acquired using a modified Siemens FID sequence (hard pulse=500 μs, TR=4 s, SW=5 kHz, data points=1024, and acquisition time=205 ms). ¹³C flip angle was empirically optimized to obtain maximum SNR for a given TR. A train of 20 equally spaced hard pulses (flip angle=135°) were applied during relaxation time for NOE. Stochastic waveforms¹ were used during data acquisition for proton decoupling. All proton pulses were centered at the reference water signal. The duration of each stochastic repeat unit was 0.5 ms with γ*B₂=200 Hz. To evaluate shimming condition and RF power for NOE and decoupling, ¹³C MRS was first performed on a phantom of 3-liter water bottle with 6 g NaCl. A 7-cm sphere filled with 200 mM natural abundance glutamine (Gln) and aspartate (Asp) (pH=7.0) was placed inside the bottle.

Results

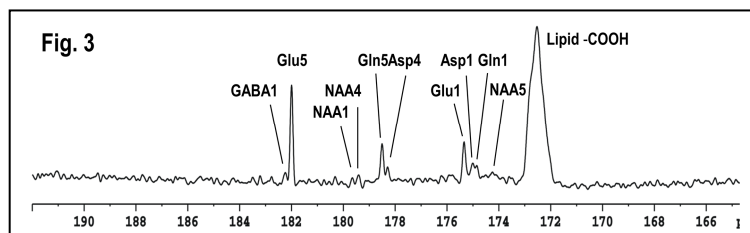
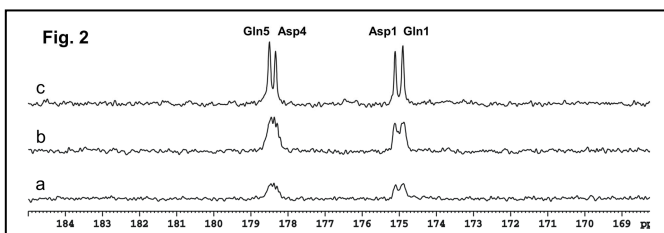
Axial gradient-echo images (Fig. 1) demonstrate that the fabricated half-volume quadrature proton coil offers adequate B₁ field homogeneity for NOE and decoupling within the effective sensitive volume of the ¹³C coil. Fig. 2 shows natural abundance ¹³C spectra (NA=64, LB=-1 Hz) acquired from the phantom without NOE and decoupling (a), with NOE only (b), and with NOE and decoupling (c). Well resolved peaks of Gln C5 (178.5 ppm) and C1 (174.8 ppm) as well as Asp C4 (178.3 ppm) and C1 (175.0 ppm) indicate that adequate decoupling was achieved. The transmit voltage reported by the scanner was 162 V (duty cycle= 0.25%) and 43 V (duty cycle=5.0%) for NOE and decoupling, respectively, which produced an averaged transmit power of 3.2 W. For a head mass of 3.5 kg, the averaged SAR was 0.90 W/kg well below the FDA threshold of 3.2 W/kg. The actual power deposition inside the human head was further reduced (up to 40%) due to additional power loss in transmission and interface box. An in vivo spectrum of a healthy subject accumulated in the last 17 minutes of [2-¹³C]D-glucose infusion (NA=256, GB=0.15, LB=-3) is shown in Fig. 3. The spectrum shows that γ-aminobutyric acid (GABA) C1 (182.2 ppm), glutamate (Glu) C5 (182.0 ppm) and C1 (175.4 ppm), Gln C5 and C1, Asp C4 and C1, as well as N-acetylaspartate (NAA) C4 (179.6 ppm), C1 (179.4 ppm) and C5 (174.3) were detected.

Discussion

A previous 3T study⁴ has shown that resonances of carboxylic/amide carbons of metabolites are not overlapped by signals from subcutaneous lipids (resonating at 172.5 ppm). Compared to the 3T study, dramatic improvement of spectral resolution was seen at 7T as expected. First the subcutaneous lipid signal is further separated from metabolite signals. More importantly the GABA C1 peak is clearly resolved from the dominant Glu C5 as shown by Fig. 3. At 7T Asp C1 and Gln C1 are also resolved. In conclusion, our results have demonstrated that carboxylic/amide ¹³C MRS with low RF power stochastic proton decoupling is clearly feasible for human brain studies at 7T. Future work will focus on improving B₀ shimming, reducing hardware noise, and optimizing pulse sequence parameters to gain maximum spectral resolution and SNR.

References

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