In Vivo ^{13}C MRS of Human Brain at 3T Using Stochastic Decoupling with a Proton Volume Coil

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Introduction

Recently, detection of [2-^{13}C]glucose metabolism in the carboxylic/amide region in human brain on a 3 T clinical scanner using low power stochastic decoupling without lipid contamination has been reported (1, 2). The advantage of low power decoupling offers an opportunity to use volume coil for proton decoupling. Here we report ^{13}C MRS of the occipital lobe of human brain using a short birdcage coil with stochastic decoupling. Volume coil proton decoupling is expected to be useful for studying many other brain regions such as the frontal lobe. Detailed specific absorption rate (SAR) analysis was performed using the finite-difference time-domain and finite-element hybrid numerical simulation (3).

Methods

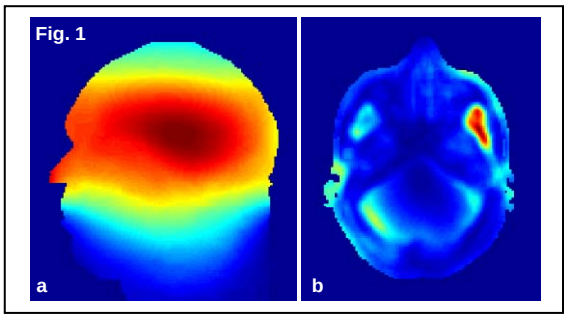
SAR analysis: The human head was modeled by 2-mm cubic Yee cells with 18 different tissue properties. The short birdcage coil (12 legs, diameter = 25.4 cm, inner length = 12.5 cm, and width of legs and end-rings = 2.54 cm) was modeled by the finite-element method with tetrahedral meshes. B_1 field and SAR distribution were calculated at 128 MHz. Local SAR was computed by averaging the absorbed electric power within a volume of 1-g mass and normalized to 1 W of absorbed RF power inside the head model with 100% duty cycle.

Experiment setup: ^{13}C MRS experiments were performed on a standard GE 3 T MRI scanner. A standalone proton decoupler was used to generate stochastic decoupling waveforms with bi-level outputs: low level pulsing during relaxation to generate NOE and high level pulsing during data acquisition for proton decoupling. The duration of stochastic repetition unit was 1.2 ms. FASTMAP method was used for high order shimming which produced a water linewdith $\leq$ 8 Hz from a 125 cm^3 cubical voxel in the occipital lobe region. A single-loop ^{13}C surface coil (dia. = 7 cm) was placed underneath the occipital lobe. ^{13}C signals were generated using a 500 µs 45^o hard pulse, TR = 4 s, SW = 5 kHz. [2-^{13}C]glucose solution (20% w/w) was infused into human subjects via an antecubital vein. The power loss due to cable and coil loading has been taken into account. The actual power was 26 W for in vivo proton decoupling and 1.0 W for NOE.

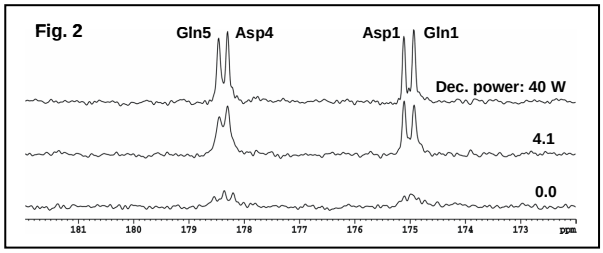
Decoupling evaluation in vitro: For the carboxylic/amide carbons of major brain metabolites, glutamine C5 and C1 peaks are most susceptible to imperfect decoupling and may overlap with aspartate C4 and C1 due to glutamine amide protons. To evaluate volume coil decoupling efficiency, natural abundance ^{13}C phantom spectra were acquired at different decoupling power levels. The ^{13}C phantom was a 7-cm sphere filled with 200 mM glutamine and 200 mM aspartate (pH = 7.0) which was placed inside a 3-liter bottle filled with distilled water and 6 g NaCl. Total amount of salt inside the bottle was > 14 g.

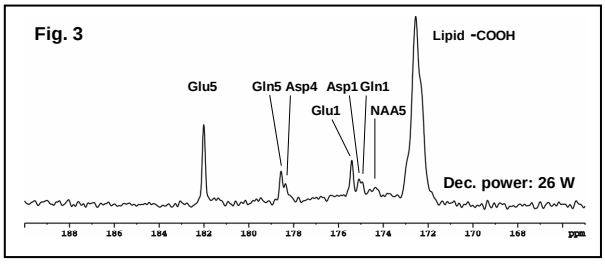
Results

B_1^+ field of the birdcage coil (Fig. 1a) is uniform and slightly stronger towards the center of the brain due to the dielectric resonance effect at high fields. The maximum normalized local SAR (1.2 W/kg) is located in the muscle in masticator space (Fig. 1b, red spot). After applying the in vivo decoupling and NOE power and the duty cycles for decoupling (5%) and NOE (95%), the maximum local SAR for our in vivo experiments is 2.7 [1.2 x (1.0 x 0.95 + 26 x 0.05)] W/kg and the average SAR is 0.56 [(1.0 x 0.95 + 26 x 0.05) / 4] W/kg assuming the effective head mass = 4 kg.



In the phantom spectra (number of point = 2048, NS = 64, LB = 1 Hz), resonances of glutamine C5 (178.5 ppm) and C1 (174.9 ppm), aspartate C4 (178.3 ppm) and C1 (175.1 ppm) are well resolved using stochastic decoupling at very low power of 4.1 W (Fig. 2). The non-decoupled spectrum is also shown at the bottom of Fig. 2 which demonstrates the necessity for proton decoupling. A 17-min steady-state spectrum acquired 90 min after the start of glucose infusion is shown in Fig. 3. The decoupling power is 26 W. Number of points = 1024, NS =256, LB = -3 Hz, and GB = 0.3. Resonances from several key metabolites, glutamate C5, glutamine C5 and aspartate C4 are spectrally resolved. Resonances from glutamate C1, glutamine C1, aspartate C1, and NAA C5 were also detected.





Discussion

The carboxylic/amide carbons of major brain metabolites could be effectively decoupled using stochastic decoupling with a volume coil as demonstrated by the phantom spectra in Fig. 2. The B_1 field efficiency of the birdcage coil is roughly 50% of that of the quadrature surface coil (3). Thus, the volume coil would need four times the decoupling power of the surface coil. However, the uniform B_1 distribution of the volume coil undoubtedly improves the decoupling efficiency. The actual increase in decoupling power using volume coils is much less. The actual decoupling power using the volume coil in the in vivo study was 26 W which is similar or less than that using the quadrature surface coil to decouple protonated alkanyl carbons (30 W) at 4.0 Tesla (4, 5). The advantage of low power decoupling using volume coil with [2-^{13}C]glucose infusion provides opportunities to perform proton decoupling in the frontal lobe of human brain and to acquire proton decoupled ^{13}C MR spectra with multi-^{13}C receive coils to further increase SNR and spatial coverage.

Reference

1. S Li, *et al*. ISMRM Proceeding 2007, Abst. 53; **2.** S Li, *et al*. ISMRM Proceeding 2008, Abst. 1560; **3.** S Li, *et al*. ISMRM Proceeding 2008, Abst. 783. **4.** R Gruetter *et al.* Magn Reson Med 1996;36:659; **5.** G Adriany *et al.* J Magn Reson 1997;125:178.