Short-echo, single-shot, full-intensity ^{1}H MRS of the Human Brain at 4T

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Introduction

Short echo time ^{1}H MR spectroscopy techniques are critical for extending the neurochemical information beyond NAA, creatine and choline and for the detection of brain metabolites with J-coupled spin systems, such as glutamate and glutamine. Short TE minimizes signal loss due to J-evolution and T_2 relaxation, which is especially important at high fields in the human brain where T_2 values are short. Neurochemical profiles have been mostly quantified using localization with the ultra-short TE STEAM sequence (1), which utilizes half of the available magnetization. Recently, the SPECIAL pulse sequence was introduced (2), which enables full signal intensity acquisition at ultra-short echo times. However, localization with this hybrid ISIS/spin echo sequence relies on an add-subtract scheme. The LASER sequence (3) also enables localization with full signal intensity, but necessitates longer echo times because of 3 pairs of adiabatic 180º pulses. The aim of this study was to develop and optimize a single-shot, semi-adiabatic localization method with full signal intensity, short TE and minimal chemical shift displacement error for human brain ^{1}H MRS at 4T. This new method was used to obtain neurochemical profiles from the cerebellum and brainstem of healthy volunteers and compare them to STEAM data acquired from the same VOI.

Methods and Subjects

Twenty three healthy volunteers (11 M/ 12 F, 33 ± 12 years) were scanned at 4 T using a TEM RF coil (4). Spectra from the cerebellar vermis (10×25×25 cm^3), cerebellar hemispheres (17×17×17 cm^3) and pons (16×16×16 cm^3) were acquired both with the newly developed semi-LASER sequence (TR/TE = 4500/24 ms, number of transients NT = 64, Fig. 1) and a STEAM sequence (TR/TM/TE = 4500/42/5 ms, NT = 128) (1). Both sequences were combined with VAPOR water suppression interleaved with outer volume suppression (OVS) for improved localization (1). Bandwidths of the slice selective 90º pulses and 180º adiabatic full passage (AFP) pulses were 3.4 kHz and 7.2 kHz, respectively. Metabolites were quantified with LCModel (5) using unsuppressed water as reference. Only results with Cramér-Rao lower bounds ≤ 50% were included in the analysis.

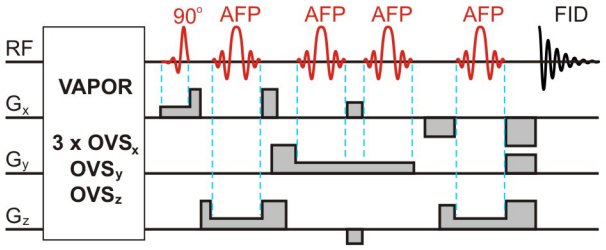

Fig. 1. The scheme of the modified semi-LASER sequence. Three pairs of OVS pulses are applied in the x-dimension selected by the slice selective excitation pulse. AFP: adiabatic full passage.

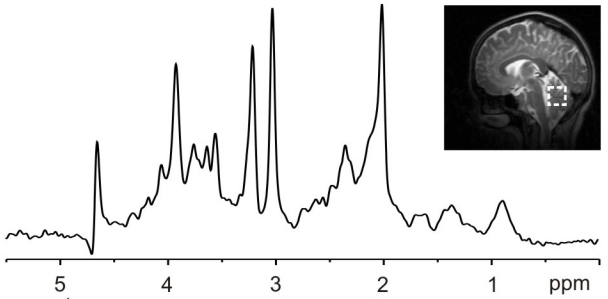

Fig. 2. ^{1}H MR spectrum acquired at 4T from the cerebellar vermis (VOI shown on the T_2 weighted image) of a healthy volunteer with the semi-LASER sequence (TE = 24 ms, TR = 4.5 s, 64 transients).

Results and Discussion

Shortening of the TE was achieved by replacing one pair of AFP pulses in the LASER sequence by an asymmetric slice selective 90º RF pulse. In addition, the order of the slice selective AFP pulses was modified (Z-Y-Y-Z) for improved suppression of unwanted coherences with shorter gradient pulses (Fig. 1). The available B_1 of the TEM coil (~24 μT) allowed shortening of the TE to 24 ms. J-modulation was substantially reduced by the array of AFP pulses and the spectral pattern closely resembled STEAM spectra with TE = 5 ms (Fig. 2). Broadband RF pulses minimized the chemical shift displacement errors. A nearly two-fold increase in SNR relative to STEAM spectra allowed frequency and phase correction in single-shot FIDs acquired from 4-6 mL VOI, which is particularly important for patient studies. Neurochemical profiles obtained with the semi-LASER and STEAM sequences were nearly identical (Fig. 3). Furthermore, the metabolite concentrations measured with these two sequences were highly correlated, indicating detection of inter-subject differences in metabolite concentrations (Fig. 4). These data demonstrate that the semi-LASER sequence enables reliable quantification of extended neurochemical profiles with data acquired over 5 min from clinically relevant brain regions.

References: 1. Tkac et al, *Magn Reson Med*, 62: 868, 2009. **2**. Mlynarik et al, *Magn Reson Med*, 56: 965, 2006. **3.** Garwood & DelaBarre, *J Magn Reson*, 153: 155, 2001. **4.** Vaughan JT et al, *MRM*, 32: 206, 1994. **5.** Provencher SW, *MRM*, 30, 672, 1993.

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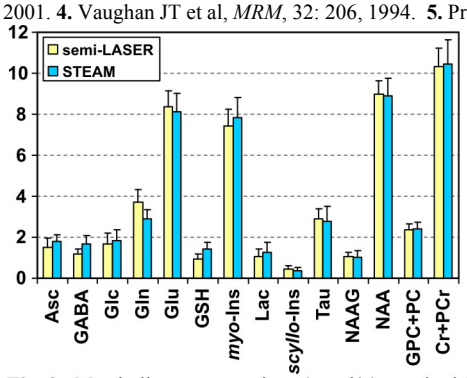

Fig. 3. Metabolite concentrations (μmol/g) acquired from the cerebellar vermis with the semi-LASER and STEAM sequences. Error bars are SD between subjects (N=21).

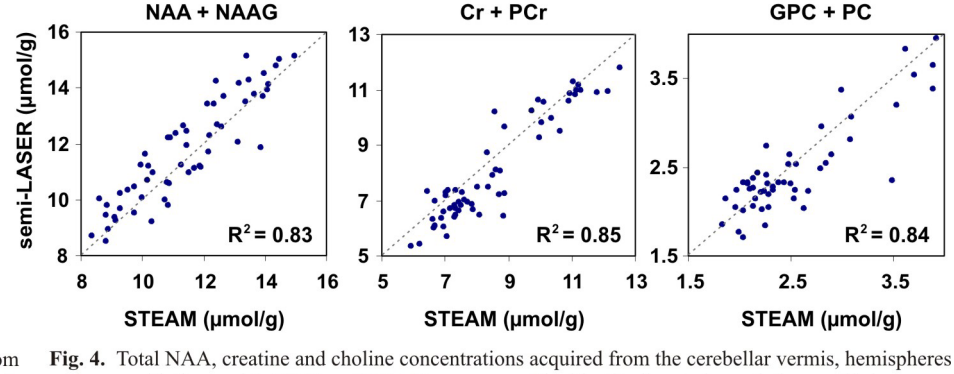

Fig. 4. Total NAA, creatine and choline concentrations acquired from the cerebellar vermis, hemispheres and pons with the semi-LASER vs. STEAM sequences. The identity line and correlation coefficients are also shown on each plot.