In vivo short spin-echo 1H MR spectroscopy with macromolecule suppression

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Introduction

It has been demonstrated that the ultra-short spin-echo proton MR spectroscopy at high magnetic fields provides a powerful tool for *in vivo* neurochemical quantification of the brain.[1] Other than the STEAM sequence, the SPin ECho, full Intensity Acquired Localized (SPECIAL) spectroscopy has been proposed to achieve full signal-intensity acquisition with ultra-short spin-echo time (~ 2.2 ms).[2] Compared to the PRESS sequence, shorter TE and larger RF pulse bandwidth are achieved. In the current work, a modified outer-volume suppression (OVS) scheme is proposed to compensate the potential subtraction error of the ISIS module in SPECIAL.

The macromolecule (MM) contribution to the short TE spectroscopy may lead to incorrect estimations of metabolite concentrations. Although LCModel[3] is able to estimate the MM contribution using flexible baseline and simulated MM spectra in the basis set[1], it cannot completely capture all features of the highly variable MM spectrum. In the current work, an MM suppression scheme is proposed using a modified SPECIAL sequence. A similar SNR as the STEAM spectroscopy is achieved, while flatter baseline, lower MM intensities, and improvements of Cramer-Rao lower bounds (CRLB) of some metabolites are observed with this scheme.

Methods

Experiments were performed on a healthy male Sprague-Dawley rat with a weight of 300 g. The animal was anesthetized with 2% isoflurane in 3:1 mixture of oxygen and air. MRI measurements were performed on a Bruker Biospin 9.4T scanner with a birdcage coil for RF excitation and a single-turn circular surface coil for signal reception.

A delay of 850 ms was inserted between the ISIS and the spin-echo module of the SPECIAL sequence to achieve macromolecule suppression (MMS). Spectra were acquired from the prefrontal cortex, striatum, and hippocampus with voxel sizes of 4×4×4 mm^3, 4×4×3 mm^3, 3.2×3×2.5 mm^3, respectively, using STEAM (TE/TR = 2/3000 ms), SPECIAL (TE/TR = 6/3000 ms) and MMS-SPECIAL. Number of averages were 256, 400, and 600 respectively for prefrontal cortex, striatum, and hippocampus. Water unsuppressed spectra were used for eddy current correction and metabolite quantification using LCModel[3]. For the SPECIAL sequence an asymmetric 90º pulse[3] with a bandwidth of 10 kHz was used for 90° excitation. Due to the maximum power limitation of the transmitter, a LASER module, which is a double spin-echo using full passage adiabatic pulses, was used instead of a single refocusing pulse. A full passage hyperbolic secant pulse with a bandwidth of 10 kHz was used for both the LASER and ISIS modules. Three OVS modules were interleaved with the CHESS elements of the VAPOR scheme[4]. A full passage hyperbolic secant pulse with a bandwidth of 50 kHz was used for 90º excitation in a non-adiabatic manner. The slice thickness of the excitation in OVS was set to 20 mm to cover almost all the outer volumes detectable by the surface coil.

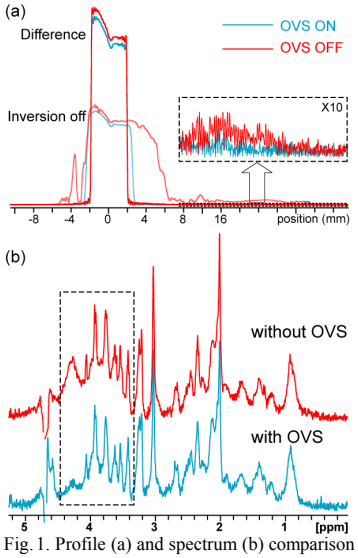

Fig. 1. Profile (a) and spectrum (b) comparison of OVS ON/OFF taken at prefrontal cortex.

Results and discussions

The ISIS module was used for the localization of the anterior-posterior direction. The OVS module achieved excellent suppression efficiency and paved the way for the localization (Fig. 1a: Inversion off). The expanded inset of the localization profiles shows the incomplete suppression of outer volume when OVS was off. As a result, distorted baseline can be seen at the frequencies > 3.4 ppm in the spectrum without OVS (Fig. 1b). The striatum spectra of STEAM, SPECIAL and MMS-SPECIAL are presented in Fig. 2. The MMS-SPECIAL spectrum results in a flatter baseline compared to the other two methods. The SNR of MMS-SPECIAL remains the same level as STEAM in three regions, while MM signals at ~ 1.0 ppm are suppressed by 70-75%. The measurements of NAA and Glu by the three methods are in good agreement with each other. MMS-SPECIAL resulted in substantially reduced CRLBs for NAAG. The subtraction of the overlapping MM signal may more accurately account for the contribution of MM around 2.0 ppm than the spline baseline determined by LCModel. The concentration values measured by MMS-SPECIAL are subject to T1 weighting. The optimization of the LCModel fitting parameters for MMS-SPECIAL is currently under investigation as well as optimizing the inversion delay time to determine if MM suppression efficiency can be further improved.

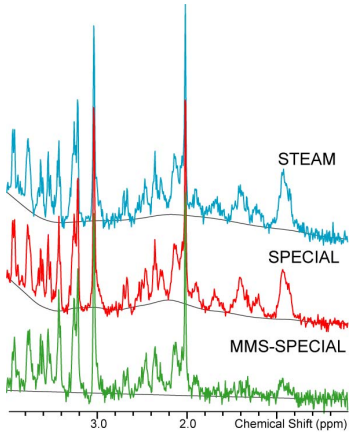

Fig. 2. STEAM, SPECIAL and MMS-SPECIAL spectra taken from striatum with a voxel size of 4×4×3 mm^3. The SPECIAL spectrum was scaled by 0.5 to match the absolute intensities of other two.

Table 1. Comparisons of STEAM, SPECIAL and MMS-SPECIAL spectra. Quantification is performed using LCModel. IU= institutional unit, CRLB= Cramer-Rao lower bounds

	Prefrontal cortex			Striatum			hippocampus		
	STEAM	SPECIAL	MMS	STEAM	SPECIAL	MMS	STEAM	SPECIAL	MMS
SNR	34	65	35	24	42	23	21	40	19
MM (IU, CRLB)	11.3 (7%)	8.7 (9%)	3.1 (10%)	11.7 (8%)	9.5 (9%)	3.0 (15%)	11.5 (8%)	9.7 (6%)	3.5 (17%)
NAA (IU, CRLB)	5.9 (3%)	6.1 (3%)	6.3 (3%)	5.6 (4%)	5.4 (4%)	5.7 (4%)	7.1 (4%)	7.2 (3%)	7.6 (4%)
NAAG (IU, CRLB)	0.5 (32%)	0.4 (37%)	0.8 (19%)	0.5 (32%)	0.2 (59%)	0.7 (18%)	0.5 (40%)	0.4 (32%)	0.8 (25%)
Glu (IU, CRLB)	6.5 (4%)	7.1 (3%)	7.4 (3%)	5.6 (6%)	5.6 (5%)	5.6 (6%)	6.6 (6%)	6.6 (4%)	7.2 (6%)

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