SPECIAL-COSY at 7T

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Introduction

Metabolites of particular interest are neurotransmitters and their precursors such as glutamine (Gln), glutamate (Glu), N-acetyl-aspartyl-glutamate (NAAG) and gamma amino butyric acid (GABA), as well as antioxidants such as glutathione (GSH) and ascorbic acid (Asc / vitamin C), whose important roles in the pathophysiology of neurological and psychiatric disorders is still not fully understood [6]. These metabolites are only present at low concentrations and hence give rise to small signal intensities and exhibit complex multiplet structures due to the effect of J-coupling. Their independent quantification is impossible by conventional 1D magnetic resonance spectroscopy at clinical field strength (1.5 or 3T) due to strong spectral overlap of individual signal contributions that partly stem from much more intense resonance lines. To reduce spectral overlap and to increase the number of detectable metabolites especially at low field strength of 1.5 and 3T as used in a clinical environment, a number of spectral editing [] and 2D (spectral) spectroscopy [] methods have been adopted for in vivo ^{1}H MRS. All methods exploit differences in scalar coupling between metabolites with overlapping resonance lines. The obvious advantage of 2D MRS methods is that they are not tailored to detect only one metabolite but the whole range of available metabolite signals. An alternative approach to detect these metabolites of interest is the exploitation of the largely increased spectral separation at ultra-high field strength. However, at 7T, which became recently available for the application in humans, there is still considerable overlap between metabolite signals which hampers their independent quantification.

To maximize the number of reliably quantifiable brain metabolites we thus propose to combine ultra-high strength (7T) with 2D magnetic resonance spectroscopy such as COSY. To make COSY applicable to in-vivo MRS volume localization has to be incorporated. Different localization schemes like L-COSY [1], VOSY-COSY [2], SLO-COSY [3] or PRESS localized COSY have been proposed in literature. A major disadvantage of the just mentioned methods is the fact that all of them use at least 2 slice selective refocusing pulses to localize a 3D voxel. Especially at 7T where a lot of coupled spin systems which are of particular interest exhibit rather short relaxation times the unnecessary long free evolution period and additional localization pulses before the actual COSY mixing pulse in schemes like L-COSY impose limits on the detectability of these resonances. Mlynárnik et al. [4] proposed the combination 1D ISIS and 2D spin echo encoding for a localization scheme called SPECIAL and demonstrated excellent spectral quality and information content due to very short echo times. In this work, the SPECIAL scheme was adapted for localized 2D COSY spectroscopy on 7T to limit the number of refocusing pulses to the absolute minimum needed to encode COSY and thus exploit as much signal as possible from coupled resonances in presence of short T2 relaxation times.

Materials & Methods

SPECIAL-COSY was implemented on a Philips 7T Achieva MR system. A trapezoidal adiabatic inversion pulse was used together with 2 asymmetric 90 degree pulses. An additional prefocusing gradient was included in the sequence to compensate for the echo pulse asymmetry and to obtain a flat phase response over the echo volume. A specifically optimized version of VAPOR [5] that considers the two ISIS encoding steps separately was used for water suppression. To compensate for magnetization transfer artifacts from skull lipids a off-resonance MT compensation pulse was applied during odd ISIS encoding steps. The second frequency dimension was encoded with 64 echo time increments of 1.6ms respectively leading to a bandwidth of 625Hz in t1 and a frequency resolution of about 19Hz in F1. The data were acquired with a 16 channel head coil. A phantom containing brain metabolite in physiological conditions was used for initial measurements. In addition in-vivo SPECIAL-COSY experiments were performed in a healthy volunteer. The voxel (30x30x30mm) was placed into the visual cortex area. The minimum achievable echo time was TE=16ms and a repetition time T of 3800ms was used. The resulting data matrix was zero filled to double the initial size, filtered by a shifted Gaussian filter in the direct dimension and a sine bell filter in the indirect dimension.

Results & Discussion

In-vitro (Figure 1) and in-vivo (Figure 2) localized 2D COSY spectra acquired at 7T using the SPECIAL localization technique showed good spectral quality with a low artifact content and sufficient signal-to-noise to detect several cross-peaks from the coupled spin systems of interest. The spectral information content is currently evaluated using 2D prior-knowledge fitting (ProFit)-based quantification, which has been previously successfully applied to physiological studies based on 2D JPRESS at 3T [6],. SPECIAL-COSY might also be combined with a transmit-receive surface coil at 7T to achieve even lower echo times and even higher SNR for future in-vivo studies.

[1] Thomas et. al., Magnetic Resonance in Medicine 46:58–67 (2001)
[2] Brereton et. al., Magnetic Resonance in Medicine 32:251–257 (1994)
[3] Blackband et. al., Journal of Magnetic Resonance 79:184–189 (1988)
[4] Mlynárik et. al. Magnetic Resonance in Medicine 56:965–970 (2006)
[5] Tkác et. al., Magnetic Resonance in Medicine 41, 1999
[6] Walter et al; Archives of General Psychiatry 66(5), 478-486, 2009.

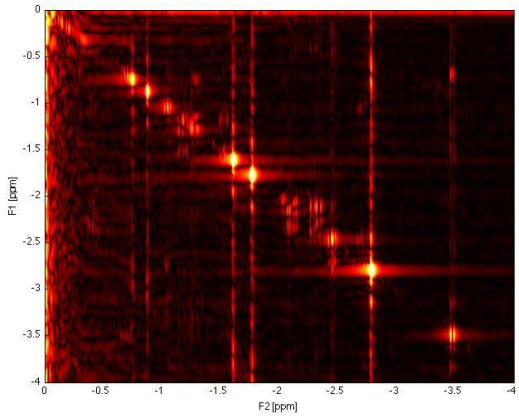

Figure 1 SPECIAL-COSY spectrum in a phantom filled with brain metabolites.

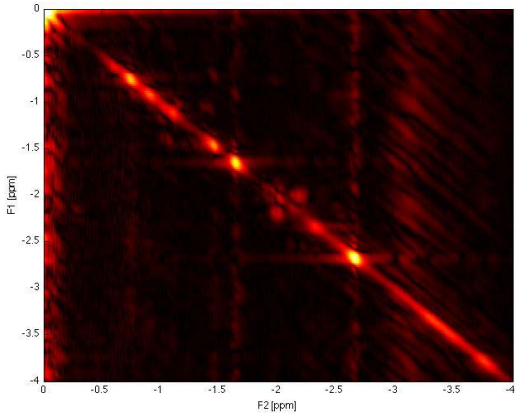

Figure 2 SPECIAL-COSY spectrum from the visual cortical area of a healthy volunteer.