^{1}H NMR spectroscopy using high performance gradients at sub-millisecond echo time

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Introduction

One of the factors complicating determination of metabolite concentrations in animal or human brain by means of in vivo proton NMR spectroscopy is evolution of spectral resonances with a multiplet structure during the spin echo or stimulated echo periods. Periodic phase modulation of the multiplet components may lead to partial cancellation of the spectral lines and to the decrease of overall intensity of the multiplet. It is thus useful to maintain the echo time as short as possible (1). Using increased gradient performance recently made available, the aim of the present study was to implement and test the feasibility of accomplishing an 800 μs echo time STEAM protocol for measuring proton spectra in rat brain at 9.4 Tesla.

Experimental

Spectra were measured from the brain of 8 days old rat pups. The ultra short echo time STEAM protocol was implemented on a Varian INOVA imaging spectrometer equipped with a 9.4 T actively-shielded 31 cm bore magnet (Varian/Magnex Scientific). An actively shielded 12 cm inner diameter high-performance gradient coil (Varian/Magnex Scientific) with a rise time of 120 μs and a maximum gradient strength of 400 mT/m was used. The effects of eddy currents (EC) were compensated to below 0.01% and < 5Hz for B_0 following a 1 s gradient pulse of 120 mT/m. EC performance was approximately 5-fold improved compared to previous 9.4 T configurations (1), since the rise time was reduced from 500 μs to 120 μs and the strength was increased to 400 mT/m. Yet the EC fields were almost nonexistent along X and Y axes and strongly reduced along Z. The excellent gradient performance enabled to start the signal acquisition 150 μs after switching off the last spoiling gradient pulse without any additional line distortion. A 14 mm diameter two-loop quadrature coil was used both for RF excitation and signal reception. Field homogeneity was adjusted by the FASTMAP protocol (2).

The optimized STEAM protocol used asymmetric RF pulses for slice selection as previously published (1). The size of VOI was 4mm×2.5mm×4 mm, TR = 4 s, TE = 800 μs, TM = 20 ms. Signal from the outer volume was suppressed by four blocks of 1.2 ms hyperbolic secant slice selective pulses, water signal was suppressed by the VAPOR sequence (1). The measured data were not eddy-current corrected.

Results and discussion

To achieve the shortest echo time, the length of the excitation pulses was reduced to 350 μs and the duration of the spoiling gradients to 100 μs. The amplitude of the gradients was manually optimized to retain the optimal signal. A spectrum from the brain of a rat pup is shown in Fig. 1. The linewidth of the water signal before its suppression was less than 11 Hz. The spectrum has the characteristic pattern (3) with low NAA (2.01 ppm) and shows absence of spurious signals. Signals of less abundant or poorly resolved metabolites, e.g. phoshoethanolamine (PE) at 3.97 ppm, resolved spectral lines of CH_2 protons of phosphocreatine (PCr) and creatine (Cr) at 3.93 ppm and 3.91 ppm, respectively, NAAG at 2.04 ppm and lactate (Lac) at 1.32 ppm were clearly discernible. Compared to the spectra measured with TE = 2 ms, the broad peaks of macromolecules were more intense. We conclude that the use of the high performance gradients enables to measure localized STEAM spectra with features reminiscent of spectra obtained by the pulse-and-acquire technique.

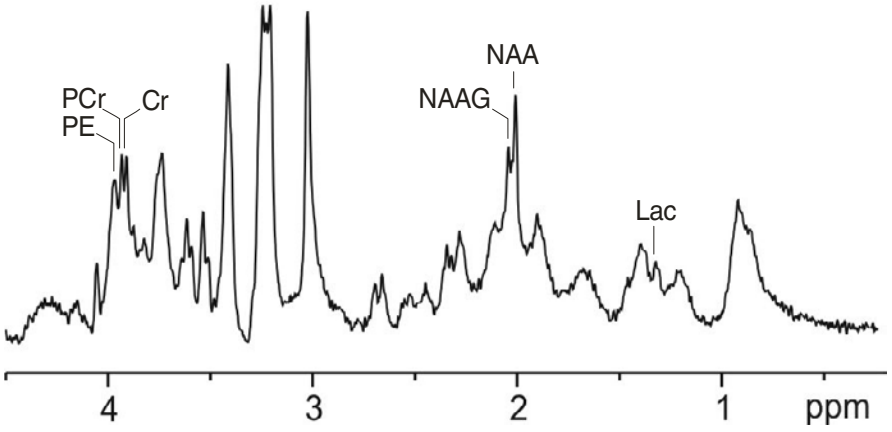

Fig. 1. A sub-millisecond STEAM spectrum of brain of a rat pup from the region of basal ganglia

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References

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