Short-TE proton spectroscopic imaging of the neurochemical profile in the rat brain at 1 µl resolution

V. Mlynarik[1], G. Gambarota[1], I. Kohler[1], and R. Gruetter[1,2]

[1]Laboratory for Functional and Metabolic Imaging (LIFMET), Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, [2]Departments of Radiology, Universities of Lausanne and Geneva, Switzerland

Introduction: Proton short-echo-time localized spectroscopy offers a wealth of information on the concentrations of many important metabolites in various brain regions of rodents (neurochemical profile) such as striatum, cortex, hippocampus or cerebellum (1,2). High resolution spectroscopic imaging, on the other hand, can provide similar information simultaneously at high spatial resolution, but covering a larger region in brain. The aim of this study was to show that short-echo-time spectroscopic imaging of the neurochemical profile in the rat is feasible with high spatial and spectral resolution and with sufficient signal-to-noise for the quantification of metabolites other than NAA, tCr, Cho, Glx and Tau.

Experimental: The data were measured on the brain of three adult Sprague-Dawley rats. The SPECIAL spectroscopy sequence (3) (TR/TE = 2000/2.8 ms) with phase encoding in the horizontal plane (Fig. 1) was implemented on an actively shielded 9.4 T/31 cm spectrometer (Varian/Magnex Scientific). A home-built 14 mm diameter quadrature coil was used both for RF excitation and signal reception. Field homogeneity was adjusted by FASTMAP (4). The nominal size of the excited VOI was 9×2×10 mm^3. Two acquisitions were collected for each of the 32×32 phase encoding steps using FOV of 24 mm×24 mm, giving a nominal voxel size of 0.75×0.75×2 mm^3 (1.1 µl). The *k*-space data were then filtered with a Gaussian function in two spatial domains. From the spectra of individual voxels, the neurochemical profile was determined using LCModel (5). Reference water signals were measured using the same protocol without water suppression and with TR=1.5 s. The total measurement time, including both metabolite and water scans was 2 hours.

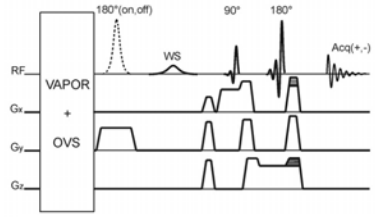

Fig. 1. Pulse sequence for SPECIAL spectroscopic imaging

Results and Discussion: The SPECIAL technique provided full signal intensity available in the excited region, thus allowing high spatial resolution in a reasonable measurement time. Spectra from outer voxels were potentially affected by chemical shift displacement errors of the localization sequence. Therefore, only the inner region of the VOI consisting of 9×12 voxels was quantified (Fig. 2). Based on a brain atlas, this region included the hippocampus (Hip) (the upper part of metabolic maps), corpus callosum (CC) with caudate putamen (CPu) (the middle part), and frontal cortex (Cort) with corpus callosum (the lower part). Characteristic concentration patterns were seen for a number of metabolites (Fig. 3): creatine was higher in Hip and Cort than in CC, choline was higher in Hip and CC than in Cort, glutamine and GABA were higher in Hip and Cort and lower in CC, myo-inosiol was much higher in Hip and slightly higher in Cort than in CC, taurine was much higher in Cort and slightly higher in Hip than in CC, and PE was higher in Cort than in Hip and CC. The differences in metabolite concentrations between Cort and Hip were in excellent agreement with previously published data (1). By summing several spectra from voxels containing large fractions of CC and Hip, respectively, and showing optimal linewidth, high-quality spectra of these cerebral structures were obtained with greatly reduced partial volume effect (Fig. 4). The relative decrease of Cr, Ins and Tau in the spectrum of CC was clearly visible and the differences in absolute metabolite concentrations agreed with those found in human Hip and in temporal lobe white matter (6).

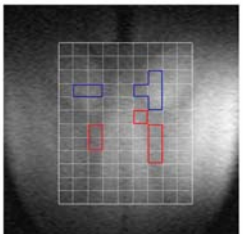

Fig. 2. Morphological image of the rat brain

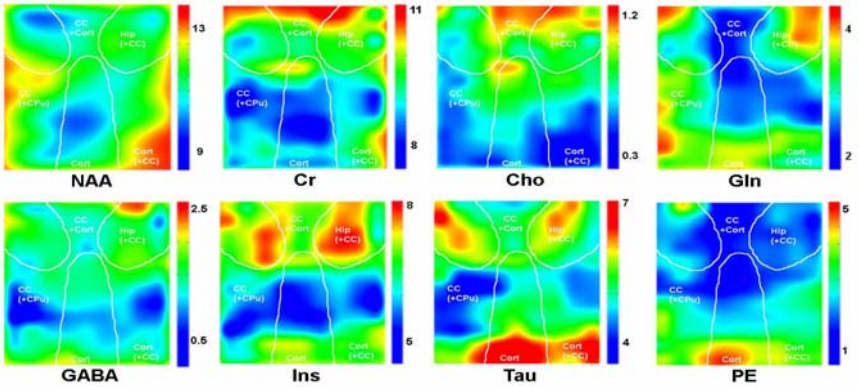

Fig. 3. Metabolic maps for the region shown in Fig. 2. Numbers at color bars indicate concentration ranges in mmol/kg.

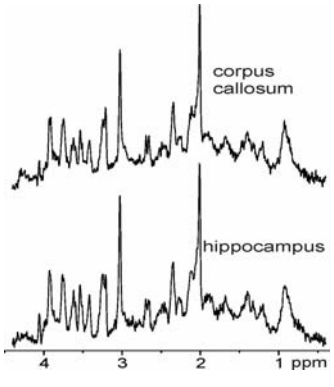

Fig. 4. Summed spectra from CC and in Hip (red and blue voxels in Fig. 2, respectively)

Conclusions: We concluded that high-resolution short-echo-time proton spectroscopic imaging at 9.4 T can be used to measure the spatial distribution of the neurochemical profile in the rat brain at µl resolution. Application of this technique at even higher magnetic fields such as 14.1 T can improve SNR, which should permit spectroscopic imaging with µl resolution of the entire neurochemical profile in ~1 hr experiment time.

Acknowledgments

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References

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