# In Vivo Spectroscopy at 11.7 Tesla Using a Low Cost 89-mm Bore Vertical Microimager

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**Introduction**

Chemical shift dispersion is proportional to field strength. High field spectroscopy allows spectral resolution of signals overlapping at low field strength. However, $B_0$ inhomogeneity, which is also proportional to field strength, could diminish the resolution gains promised by high field magnets. The purpose of this study is to demonstrate that reproducible, high-quality in vivo spectroscopy data can be obtained using low cost, widely available, vertical 89-mm bore magnets.

**Method**

All experiments were performed on a microimaging spectrometer interfaced to an 11.7 Tesla 89-mm bore vertical magnet sited in an unshielded standard laboratory room. The spectrometer is equipped with a 57-mm i.d. gradient (3 G/mm @ 100 μs) for in vivo NMR imaging and spectroscopy experiments. In vivo $^1$H and $^1$H[$^{13}$C] experiments were performed using a home-built surface $^1$H (diameter: 15-mm) or concentric surface $^1$H (circular, diameter: 15-mm)/$^{13}$C (square, 25 x 25 mm$^2$) RF coil systems mounted on an integrated home-built animal handling system capable of rat body support, head fixation, physiology monitoring, coil tuning and RF shielding. Male Sprague-Dawley rats (150-200 g) were orally intubated and mechanically ventilated with a mixture of ~70% $N_2O$, 30% $O_2$ and 1.5% isoflurane. The left femoral artery was cannulated for periodically sampling arterial blood to monitor blood gases ($pO_2$, $pCO_2$), pH, and glucose concentration, and for monitoring arterial blood pressure levels. Two femoral veins (left and right) were also cannulated for intravenous infusion of α-chloralose and $^{13}$C-labeled glucose. After surgical preparation, isoflurane was discontinued and pancuronium bromide was administrated to maintain immobilization. Rectal temperature was monitored and maintained at 37.5 ± 0.5 °C using an external pump for heat exchange by water circulation. Typically, arterial blood $pO_2$, $pCO_2$, mean blood pressure, and pH were maintained at 150-170 mmHg, 35-45 mmHg, 180 ± 30 mmHg, and 7.35-7.45, respectively. Heart rate, end-tidal $CO_2$, and tidal pressure of ventilation were also monitored. The rat brain was shimmed automatically using previously described method (1). Usually a 9-13 Hz half-height line width for the metabolites was obtained from 4.5 x 2.5 x 4.5 or 4 x 2.5 x 4 mm$^3$ (40-50 μL) spectroscopy voxels. The pulse sequence used (1) is shown in Fig. 1. For short-TE $^1$H spectroscopy, the $^{13}$C pulses are switched off. For $^1$H[$^{13}$C] (POCE) spectroscopy, the carbon pulse was switched on during even-numbered scans and off during odd-numbered scans. The odd-numbered and even-numbered scans were stored in separate data blocks. Protons bound to $^{12}$C were edited out by subtracting the even-numbered scans from the odd-numbered scans.

Fig 1

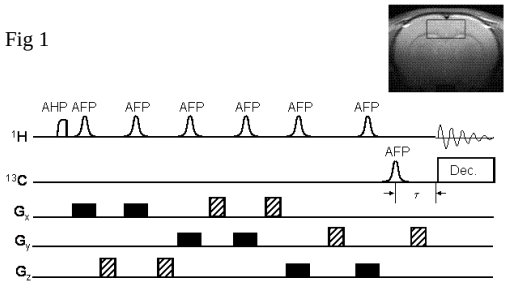



Fig. 2

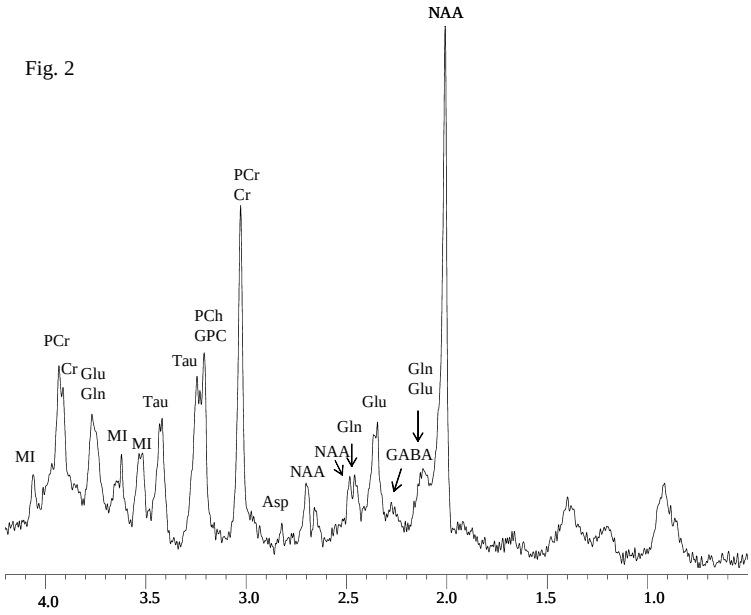
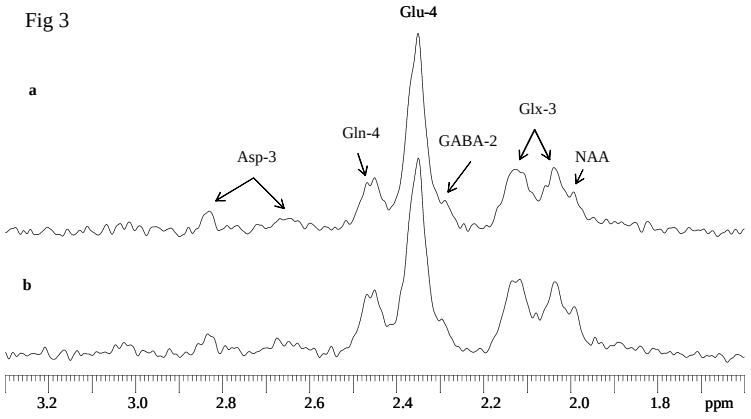



Fig 3




**Results and Discussion**

Fig. 2 shows a typical short-TE $^1$H spectrum (NS = 128, TR/TE = 2700 ms/15 ms, LB = 1 Hz). No resolution-enhancing widow functions were used. The spectrum was phased using zero-order phase only. No baseline corrections were used. The phosphocreatine methylene peak at 3.93 ppm and creatine methylene peak at 3.92 ppm are clearly resolved. The Glu-4 signal at 2.35 ppm, the Gln-4 at 2.46 ppm, and GABA-2 (and macromolecules underneath) at 2.30 ppm are also resolved spectrally. The signal from NAAG methyl group at 2.05 ppm is also visible in some proton spectra. The lactate signal at 1.32 ppm remains very low throughout the experiment, indicating excellent physiological conditions. Fig. 3 shows two 11.5-min POCE spectra acquired from the intact rat neocortex at the 141- and 186-min intervals using WALTZ-4 decoupling after the start of [1,6-$^{13}$C$_2$]glucose infusion (TR/TE = 2700 / 22 ms, gf = 0.25, lb = -5). At the in vivo spectral resolution achieved at 11.7 Tesla, the [2-$^{13}$C]GABA signal at 2.30 ppm is spectrally resolved from the neighboring [4-$^{13}$C]Glu signal at 2.35 ppm, allowing the accurate determination of the turnover kinetics of [2-$^{13}$C]GABA from [1-$^{13}$C] or [1,6-$^{13}$C$_2$]glucose. Broadband adiabatic $^{13}$C-editing and decoupling has also been implemented (data not shown). The excellent spectral resolution achieved here is benefited from the relatively efficient high-order shims because of the narrow 89-mm bore (1). To achieve better or the same effects in high-order shimming on wider bore magnets, efficient shim design and/or strong currents for shimming would be needed.

**Reference** 1. Chen et al, Magn. Reson. Imag., 2004; 22:835.