Functional ^{1}H NMR spectroscopy in cat visual cortex

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INTRODUCTION

The visual cortex of cats has been extensively studied using different fMRI techniques to reveal details of neuronal activity which is accompanied by elevated cerebral blood flow, cerebral blood volume and cerebral oxygen consumption [1,2]. However, to the best of our knowledge, only one study has been focused on the neurochemical changes in the cat visual cortex during visual stimulation [3]. The purpose of this study was to investigate the sensitivity of high-field ^{1}H NMR spectroscopy to detect changes in the neurochemical profile of the cat visual cortex during neuronal activation.

METHODS

All NMR measurements were performed with a Varian INOVA spectrometer interfaced to a 9.4 T magnet (Magnex). First and second order shims were adjusted by FASTMAP [4]. Ultra-short echo-time STEAM (TE = 2 ms) combined with outer volume suppression and VAPOR water suppression was used for localization [5]. A transmit/receive surface RF coil was positioned close to the cat visual cortex. Metabolite concentrations were quantified using LCModel with the macromolecule spectra included in the database while the unsuppressed water signal was used as an internal reference as in our previous studies [6,7]. The cat (n = 1; 1.3 kg) was kept under isoflurane anesthesia throughout the experiment (1% in a N_2O : O_2 mixture of 70 : 30), blood pressure, end-tidal CO_2 and body temperature were maintained at normal conditions [more details in 2]. Visual stimuli consisted of binocular 40 s high-contrast square-wave moving and rotating gratings (0.15 cyc/deg, 2 cyc/s) optimized to elicit neuronal activity in the primary visual cortex of the cat. The paradigm consisted of 4 epochs (stimulation, rest, stimulation, rest) repeated 10 times.

RESULTS AND DISCUSSION

Effective shimming, localization performance, and water suppression resulted in highly resolved spectra from the cat visual cortex (Fig. 1) allowing reliable quantification of 16 brain metabolites with Cramer-Rao lower bounds CRLB < 15%. Only scyllo-Ins was quantified with CRLB < 25%. These values corresponded to an estimated precision of metabolite quantification in the range of 0.1 – 0.2 µmol/g (Fig. 2). This methodology was used to quantify concentration changes of multiple metabolites in the primary visual cortex of the cat during visual stimulation. Concentrations of all measured metabolites varied within a detection threshold range of ±0.2 µmol/g. The concentration trajectories of glucose and glutamate (Fig. 3) indicated correlation with the stimulation paradigm, where the direction and magnitude of changes correspond to values that have been observed in the human brain at 7 T by Mangia et al. These preliminary data suggest that spectroscopy at high fields has a potential to provide additional information about neuronal activity.

REFERENCES: 1. Yacoub E et al, *J Cereb Blood Flow Metab* (2005) *in press*; **2.** Harel N et al, *NeuroImage* (2005) *in press*; **3.** Kauppinen RA et al, *Euro J Neurosci* 9, 654 (1997); **4.** Gruetter R and Tkac I, *Magn Reson Med* 43, 319 (2000); **5.** Tkac I et al., *Magn Reson Med* 41, 649 (1999); **6.** Tkac I et al, *Magn Reson Med* 50, 24 (2003); **7.** Tkac I et al, *Magn Reson Med* 52, 478 (2004).

Supported by Keck Foundation, MIND Institute, NIH grants P41-008079 and EB004460

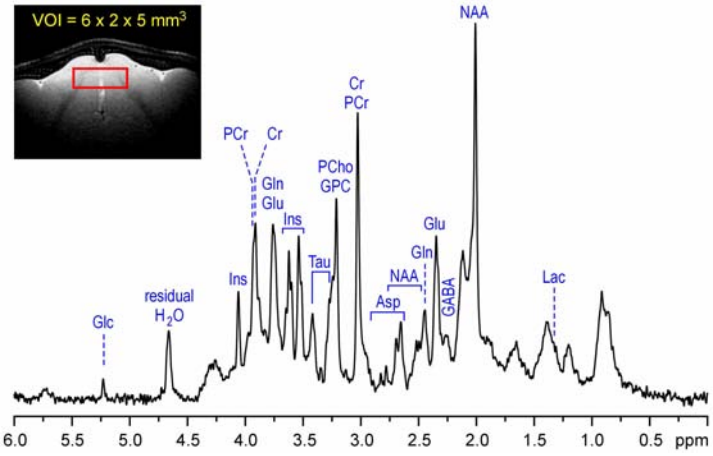

Fig. 1 In vivo ^{1}H NMR spectrum from cat visual cortex. STEAM, TE = 2 ms, TR = 5 s, NT = 80, VOI = 60 µl. Inset: coronal RARE image with the position of the VOI containing primary visual areas 17 and 18.

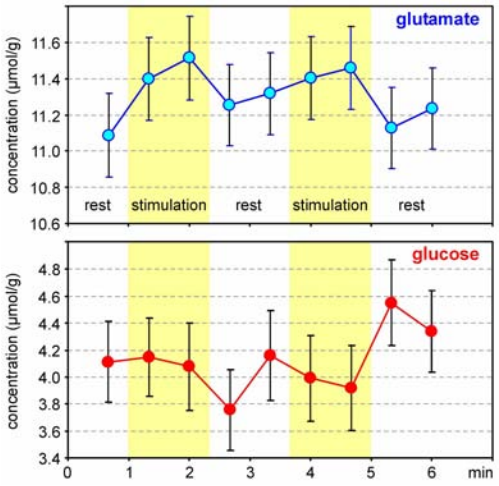

Fig. 3 Concentration changes of glutamate and glucose in the primary visual cortex during visual stimulation. Error bars represent CRLB.

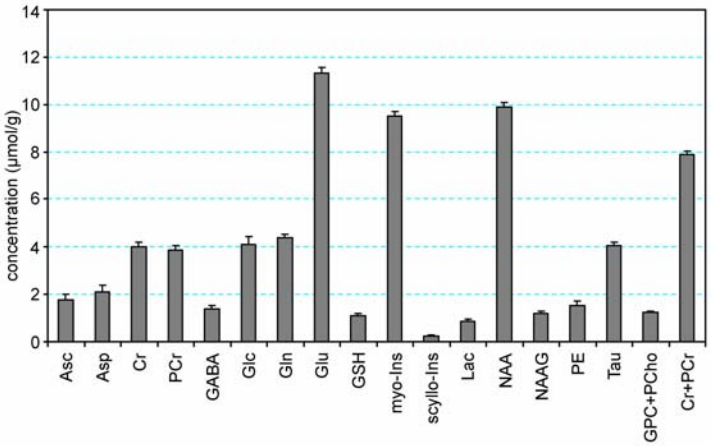

Fig. 2 Average concentration of metabolites in the cat visual cortex during stimulation paradigm (n = 8). Error bars represent SD.