Lactate Detection in Healthy Brain During Visual Stimulation Using fMRSI

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Introduction

Anaerobic glycolysis in the visual cortex due to visual stimulation has already been the subject of several magnetic resonance spectroscopy (MRS) studies more than a decade ago. Since the lactate concentration of 1 mmol/l in healthy brains is close to the detection limit of MRS at 1.5 T, single voxel (SV) experiments have so far been the method of choice for studying the temporal behaviour of the lactate concentration during visual stimulation [1,2]. It has been shown that using functional magnetic resonance spectroscopic imaging (fMRSI) the lactate response can be measured with a temporal and spatial resolution [3]. However, it was only possible to detect the lactate change in migraine patients, who show an increased metabolic response to visual stimulation compared to healthy volunteers. In this study we show that using fMRSI at a field strength of 3 T it is also possible to detect the lactate rise due to visual stimulation in healthy volunteers, with an even better spatial and temporal resolution.

Methods

All experiments were performed on a 3T Philips Intera whole body system using a send-receive head coil. 2DSI data (16x16) with a nominal spectral resolution of 2 Hz and a nominal spatial resolution of 1.25 cm were acquired from the brain of a healthy volunteer, who gave his written informed consent for this study. The SI slice of 2 cm thickness covered a FOV of 20 cm and was positioned along the calcarine fissure in the visual cortex. The spectra were acquired with an echo time of 144 ms (=1/J, J being the coupling constant of lactate), in order to distinguish the lactate signal from uncoupled macromolecular resonances in the same spectral region. To avoid signal cancellation due to anomalous J modulation, the SI data sets were acquired without PRESS volume localisation [4]. Second-order shimming was used to attain a good field homogeneity over the whole brain slice. Outer volume suppression (OVS) pulses were applied to suppress the signal from subcutaneous fat. The SI measurement lasted 5:35 minutes and was repeated six times consecutively. The first and the two last measurements were performed in darkness, whereas during the second to fourth measurement the volunteer was stimulated with a stroboscope flickering at a frequency of 8 Hz. In addition to the fMRSI measurement, functional magnetic resonance imaging (fMRI) data were obtained using the same visual stimulus to compare the region of blood oxygen level dependent (BOLD) signal change with the region of lactate change. The whole measurement was repeated twice for the same volunteer after one and two weeks, respectively, to demonstrate the reproducibility. Postprocessing of spectra included exponential filtering of the time domain signal, cosine filtering in k-space and B0 correction. All filtering parameters were kept constant for all six SI data sets of one functional measurement. Lactate and NAA as a reference metabolite were quantified integrating the modulus spectra and the time course of the Lactate/NAA ratio was examined inside and outside the visual cortex.

Results

Fig. 1 shows the time course of spectra for one voxel from the visual cortex. The lactate peak is in anti-phase with respect to the uncoupled resonances (NAA, creatine, choline). It becomes apparent that the lactate concentration increases with the onset of the visual stimulation, reaches a maximum during the third measurement and then falls off again, probably due to habituation. When the stimulus is switched off, the lactate concentration approximately goes back to its initial value. The other metabolite peaks remain unchanged during the stimulation paradigm. Fig. 2 shows the time course of the Lactate/NAA ratio for the whole SI slice. The parts of the brain where the ratio is increased by more than 250 % compared to the first measurement in darkness are highlighted on the anatomical images. The BOLD measurement showed that there was indeed an activation in the visual cortex during stimulation.

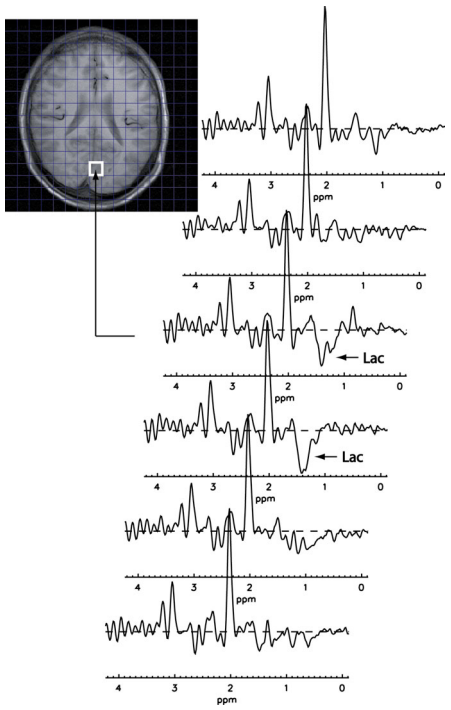

Fig. 1: Time course of spectra for a voxel from the visual cortex. The paradigm runs from bottom to top with the first and the two last spectra acquired in darkness.

Discussion

We have shown that the method of fMRSI is suitable to study the change of the lactate level during sustained visual stimulation in healthy volunteers. Due to the fairly high spatial resolution of the SI experiment the areas of metabolic changes could be identified more precisely than in SV studies and in previous fMRSI studies investigating the effects of visual stimulation. The results of this study encourage the investigation of brain pathologies such as migraine or mitochondrial encephalopathy with this method, which might enable the diagnosis of these diseases from the disturbed energy metabolism and the reduced habituation during visual stimulation in the future.

References:

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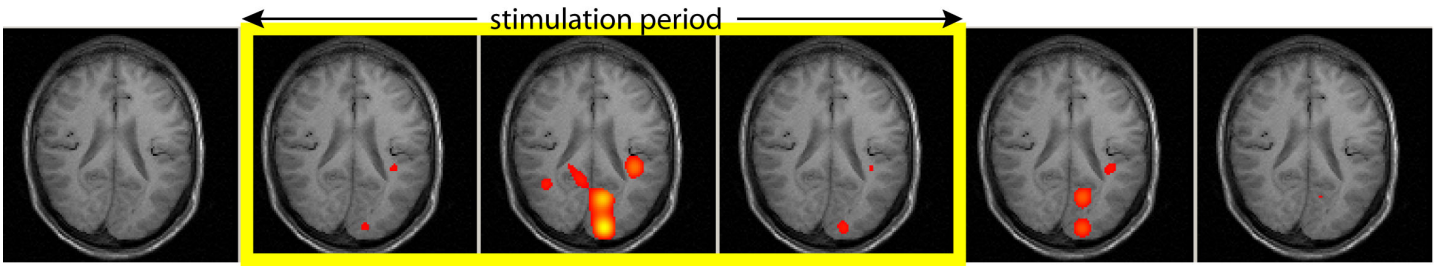

Fig. 2: Time course of the fMRSI slice with the regions highlighted, where the Lactate/NAA ratio is increased by more than 250 % compared to the first measurement.