Localized 1H MR Spectroscopy in the *alert* monkey at 7 Tesla

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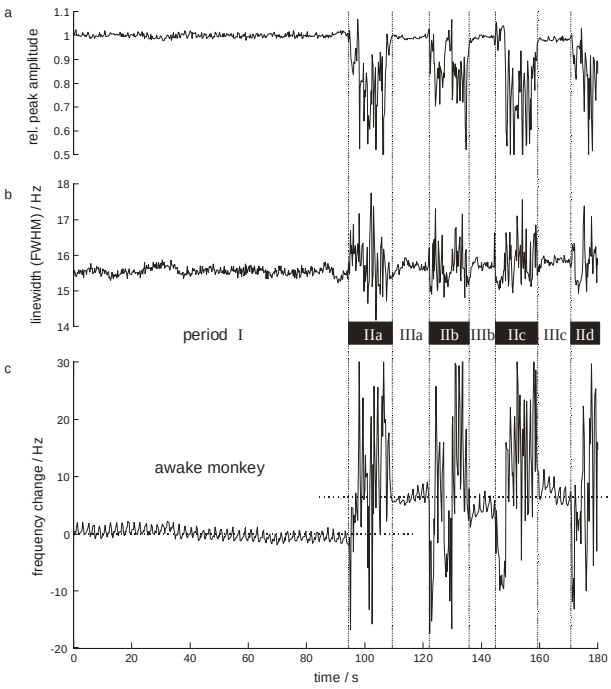
Introduction MR imaging and spectroscopy in monkeys promises to build a bridge between brain research in humans and the large body of systems neuroscience work in animals. Simultaneous fMRI and electrophysiology was recently used in macaques to elucidate the neural activity underlying the fMRI signal [1]. In this context, MRS can provide access to valuable neurochemical information, which can be linked to functional and electrophysiological results. We present here the first single-voxel ^{1}H MRS in the *alert* monkey using a 7 T MR system with a vertical bore. Typically, in electrophysiology experiments with trained monkeys, the restraint of the animal's head by means of a 3-point head post is sufficient for the acquisition of reliable data. In contrast, acquisition of quality MR spectra is sensitive to body movement. Thus, we evaluated the effects of mouth (jaw and tongue), arm, leg and rump movement on ^{1}H spectral acquisition and quality. Based on models for gross magnetic susceptibility changes during respiration, dynamic frequency shifts as well as shim changes (mostly components in the z-direction) were expected for single-voxel MRS.

Methods Upright positioning of the animal, being used over the last 50 years in all alert-monkey laboratories, was chosen for fMRI and MRS, to minimize discomfort in the animals, expedite their training process, and ensure longer cooperation during the demanding psychophysical testing. Single-voxel ^{1}H MRS was performed on a novel *vertical* 7T/ 60 cm system (Bruker BioSpec) with a 38-cm inner diameter gradient insert (80 mT/m, <200 μs) [2]. A 60-mm surface coil in transceive mode was used [3]. Localization was achieved with a short echo time STEAM sequence and VAPOR water suppression. Shimming was done with FASTMAP achieving linewidths of the water peak of 15-17 Hz in the awake animal. Spectral quantification was done with LCModel using simulated basis spectra of metabolites and macromolecules. Peak integral, amplitude and linewidth (FWHM) of the water signal as well as peak position (frequency) was determined from time or frequency data. For frequency correction, the MRS data were processed before averaging by multiplication of the FID with an inverse linear phase derived from the relative frequency changes. This could account for the significant effects of frequency variations causing line broadening.



Results and Discussion *Respiration-induced B_0 fluctuations* were approximately 2 Hz p-p in the *awake* monkey and showed significant baseline drifts. Movements of the arms and/or legs, and changes of the seat position (rump-motion) frequently did cause small (<1 Hz) but occasionally catastrophic frequency changes (up to 40 Hz p-p) depending on the type and the extent of body movement. The change of the baseline therefore could be attributed to *small* movements of the monkey inside the chair, e.g. arm or leg, which caused susceptibility-induced B_0 fluctuations at the position of the head similar to those caused by respiration. The *effect of large body movements* is shown in the figure (TR 250 ms): resting period (I), body-motion periods (IIa-d), resting periods in-between body-motions (IIIa-c). Even after large motion effects (II), again only respiration-induced 2-Hz p-p changes in the frequency and no alterations in amplitude and linewidth were observed (III). Interestingly, the frequency baseline changed to a new level at 7 Hz (likely new seat position). The linewidth of averaged water spectra was 19.1 Hz; which decreased to 15.8 Hz using the frequency correction. Since constant frequency and narrow linewidth are both critically important for high spectral quality (while amplitude mainly contributes to the SNR), a *two-step approach* was sufficient to obtain optimal results in the averaged spectra: 1) rejection of periods with major body-motion and 2) frequency correction before averaging. Significant changes in the spectral linewidth and amplitude were observed during major body-motion attributed to spatially-dependent magnetic field changes ('shim'). Small frequency changes, for example the drifting frequency baseline or periods before/after motion, were related to small body-motions and did not show a significant spatial B_0 dependence. Therefore a change of linewidth due to shim changes was minimal using a voxel size of 10 mm and smaller. *Reliable detection and quantification* up to 10 brain metabolites in the *awake* monkey was finally made possible with an error below 10% for the major concentration metabolites (see table).

conc. mean ± SE (mM), n=5	
NAA+NAAG	**10.5 ± 0.4**
Gln	**1.7 ± 0.1**
Glu	**6.7 ± 0.3**
Glu+Gln	**8.5 ± 0.2**
Cr	**4.6 ± 0.8**
PCr	**3.4 ± 0.8**
Cr+PCr (Ref.)	**8.0**
Ins	**7.2 ± 0.5**
Cho	**0.85 ± 0.13**
GABA	**1.4 ± 0.2**
GSH	**1.5 ± 0.2**
PE	**1.7**

References 1. *Nature* 412:150 (2001). 2. Proc ESMRMB, *MAGMA* 15, 377 (2002). 3. Proc ESMRMB, *MAGMA* 15, 425 (2002)

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