Localized ^{1}H spectroscopy in the primary visual cortex V1

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The primary visual cortex V1 is the elementary target, when visual function and cortical reorganization are investigated. Due to its small diameter (1.5-1.7mm for the macaque monkey), so far, localized single voxel spectroscopy was not possible in this region. In addition, especially at high fields, the quality of brain MRS in these regions is reduced by local field disturbances close to the cortex surface. In the presented study, local field distributions were explored in the visual cortex of a macaque monkey. High quality spectra can be achieved, when the MRS voxel position is selected accordingly. Regarding the achievable field homogeneity in V1 it turned out that the susceptibility difference between cortex and cranial bone is the minor problem compared to the surface vessels. Using very small voxels (0.074ml), which are more than one order of magnitude smaller than what is commonly used in a human setup, ^{1}H MRS was possible in 100% gray matter in an anatomical structure as small as V1 of the macaque monkey.

METHODS: Measurements were done on a *vertical* 7T/60cm Bruker Biospec system. The MRS setup and the handling of the macaque monkeys used for the study has been described previously [1,2]. A combination coil (T: half-volume saddle coil, R: 30mm diameter surface coil) was used in all studies. 1st and 2nd order shimming was done with FASTMAP. 3D field maps were calculated from FLASH images with ΔTE=5ms (resolution: 0.175x0.175x0.5mm^3, duration: 7min/scan). A STEAM sequence with VAPOR water suppression was used for single voxel spectroscopy (TE=4 and 10ms, TM=10ms, TR=4s). The voxel geometry in the inner brain was 5x5x5mm^3 (Fig.2). The anatomy adapted geometry in V1 was 7x1.5x7mm^3 (Fig.3). For the latter, the chemical shift displacement along the A/P direction was 0.1mm/ppm. Spectra were only zero order phased and mildly resolution enhanced. Neither first order phasing nor eddy current correction was necessary.

RESULTS: A large field gradient was induced by cortical surface vessels, whereas field changes caused by susceptibility differences of brain tissue vs. the cranial bone were of minor relevance. If the STEAM voxel was not positioned in the direct vicinity of the vessel, the field disturbances appeared to be almost linear and were correctable by 1st order shimming. For high quality brain spectroscopy, the use of field maps was very convenient for the experiment planning in advance, since it permitted the identification of regions, where brain MRS is hampered due to such anatomically caused field disturbances. Furthermore, during the experiment, 3D field maps could be used for direct line width prediction of planned voxel geometries. Thereby, the optimal voxel position regarding the minimal achievable line width within the anatomical limits could be found. With a voxel position away from the surface, 10.5Hz water and 9Hz creatine line widths (0.03 ppm) were reproducibly achieved (Fig.2). In the outer cortical layer, even in the direct vicinity of the susceptibility jump between brain tissue and the cranial bone, spectroscopy was feasible with acceptable line width, when surface vessel regions were avoided (Fig.3). So far, in this region metabolite line widths 14-19Hz have been achieved.

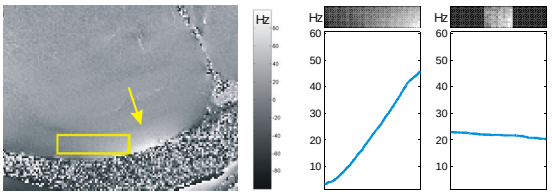
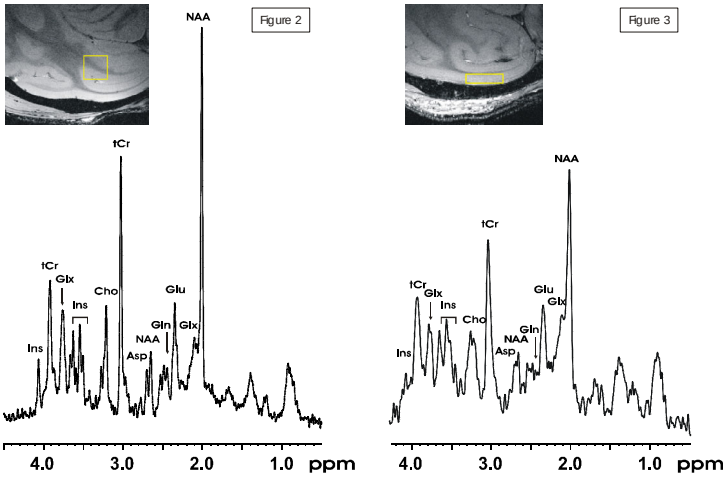


Figure 1: Axial field map of the right hemisphere visual cortex of a macaque monkey(left). The field disturbance caused by a surface vessel is visible as bright spot (arrow) close to an assumed STEAM geometry (yellow box). Field projections from right/left (center) and anterior/posterior (right) are almost linear, when the voxel position is not lying directly behind the vessel.



DISCUSSION: In practice, good field homogeneity is one of the most critical points for *in vivo* brain spectroscopy, in particular at high magnetic fields. The possibility of measuring field distributions by NMR is well known from literature. Here we have demonstrated the influence of physiological and anatomical inhomogeneity sources and that online analysis of field distributions is helpful to assess local shim/spectral quality. This helps to save experiment time and to enhance the quality of *in vivo* brain spectroscopy results. At 7T metabolite line widths of less than 10Hz can be reproducibly achieved, when sources of local field disturbances are avoided. Brain spectroscopy of very small voxels was possible in the primary visual cortex V1, profiting of the enhanced sensitivity by the use of a surface coil setup and a high magnetic field. This allows the study of metabolic and neurochemical changes related to brain function and cortical reorganization.

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