PURPOSE: Brain 1H-MRS permits in vivo detection of biochemical changes in numerous neuropathologic conditions, including cancer, multiple sclerosis or psychiatric diseases [1,2]. Absolute quantitation of metabolite concentrations (C_m in mM) allows parameter independent comparison of results obtained with variable measurement settings (B_0, TE, TR) [3]. A commonly used approach is based on multiplying the ratio of metabolite and water signals (f_M/f_W) acquired in the same MRS voxel with tissue water concentration (C_W). However, since the metabolites and brain tissue water have different T1 and T2 relaxation times, the metabolite concentrations are affected by partial volume effects. The goal of this study was to develop a correction method to estimate true metabolite concentrations from voxels containing complex mixtures of brain tissues.

RESULTS: The aim of the present work was to validate this approach by means of phantom measurements in voxels with heterogeneous metabolite and water concentrations as well as with in vivo 1H-MRS data acquired in the insular cortex (IC) of healthy controls with various repetitions times and different voxel volumes.

MATERIAL AND METHODS: All MR measurements were performed with a whole-body 3 T MR scanner (Magnetom Trio, Siemens, Germany). A circular polarized head coil (Biomedical Rapid, Germany) was used for the in vitro study, whereas the 12-channel receive only head matrix coil was used for the in vivo examinations. All MRS data was acquired with a PRESS sequence (TE 30 ms, manual shim) in voxels which were selected by means of T1-weighted 3D MRI data acquired prior to MRS (MP-RAGE TR/TE/TI = 2300/3.03/900 ms; 192 sagittal 1 mm slices, FOV = 256 x 256 mm²). The phantom consisted of a four plastic chambers (33 x 33 x 54 mm³) with aqueous N-acetyl aspartate solutions (NAA). Free water volume fractions were varied by adding D2O. As illustrated in Fig. 1, the adjusted water and NAA concentrations simulated compositions in WM (C_NAA/C_W = 50/33300 mM), GM (C_NAA/C_W = 25/44400 mM) and CSF (C_NAA/C_W = 0/55500 mM). Eight single voxel MRS scans (V: 3.5 ml) with (NEX 32) and without (NEX 16) water suppression were performed with different voxel positions to investigate the change of NAAC and GM concentrations from the WM into the GM and GM-CSF phantom together with selected positions of 8 MRS voxels.

RESULTS: Changes of in vitro NAA concentrations, calculated by assuming homogeneous (green line) and heterogeneous (orange and magenta lines) tissue compositions within the selected voxels, are shown in Fig. 2. As can be seen from the figure NAA concentrations determined by taking into account the partial GM, WM and CSF volumes (green line) are in good agreement (max. error 3.9%) with the values calculated by using the nominally adjusted NAA concentrations (black line). Contrary, NAA concentrations estimated without correction of partial volume effects are underestimated (max. error: 40.5%), especially for voxels containing CSF solution. As illustrated in Fig. 3, the adjusted water and NAA concentrations simulated compositions for both volunteer groups (GI: blue boxes; GII: green boxes) with (dashed lines) and without (full lines) taking into account the tissue composition within the MRS voxels (GI: WM/GM/CSF = 33±7/62±4/6±4%; GII: WM/GM/CSF = 22±13/66±10/12±6%). As indicated by the smaller variations between the lower and upper percentiles, corrected in vivo NAA and Cr concentrations are distributed with less scatter (max. variation: 8.2% for GI and GII with corrected data; max. variation: 3.9% for GI and GII with corrected data). The variation of tCho concentrations remained nearly the same before (max. 9.0%) and after application of the partial volume correction (max. 8.9%).

Fig. 1: Water intensities within the WM, GM and CSF phantom chambers together with selected positions of 8 MRS voxels.

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Fig. 2: In vitro NAA concentrations estimated from differently composed MRS voxels. Values were estimated by taking into account the heterogeneous voxel composition (green) as well as by assuming homogeneous voxels consisting of GM (orange) or WM (violet). The black line represents the nominally adjusted NAA concentrations.

Fig. 3: In vivo NAA, Cr and tCho concentrations for both control groups (blue: GI; green: GII) considering homogeneous (full) and heterogeneous (dashed) MRS voxels. Red lines in the boxes represent median values, whereas the upper and lower box limits correspond to the 75th and 25th percentile, respectively.