Reproducibility and variance of serial short echo time 1H magnetic resonance spectroscopic imaging of the human brain at 3T with automated planning software

S. Van Cauter[1], D. Sima[2], L. ter Beek[3], J. Luts[2], Y. Li[4], M. I. Osorio Garcia[2], S. Sunaert[1], S. Van Huffel[2], and U. Himmelreich[5]
[1]Department of Radiology, University Hospitals Leuven, Leuven, Belgium, [2]Department Electrical Engineering – ESAT/SCD, Catholic University Leuven, [3]Philips Medical Systems, [4]School of Electronical Engineering, University of Electronic science and technology of China, Chengdu, China, People's Republic of, [5]Biomedical NMR Unit/Molecular Small Animal Imaging Center, Department of Medical Diagnostic Sciences, Catholic University Leuven

Objectives: With the advent of semi-automatic data acquisition, data processing and quantification, the interest in clinical use of magnetic resonance spectroscopic imaging (MRSI) has increased. Furthermore, MRSI has been shown to be of additional value in diagnosis and therapy follow-up of multiple brain disorders. However, a lack of robust repositioning methods limits the applicability of MRSI in longitudinal studies. The purpose of this study is to validate the reproducibility of a short echo time 2D MRSI acquisition protocol using the point-resolved spectroscopy (PRESS) volume selection method (1) in two 3T MR scanners in our institution repeatedly on the same healthy volunteer. Additionally, we want to investigate the potential role of automated repositioning software of anatomical sequences (2) in the robustness of the manual placement of the CSI grid in longitudinal experiments.

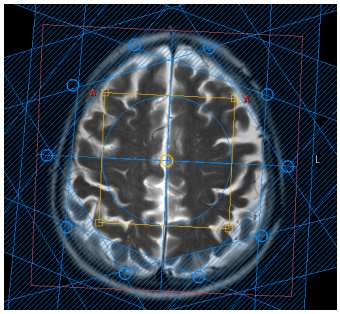

Fig. 1: positioning of the CSI

Methods: Ten healthy volunteers (age range: 23-35; average age: 28, 4 males/6 females) were imaged six times in total, three times on two different 3T MR scanners (Achieva and Intera, Philips, Best, The Netherlands). The CSI measurement was immediately repeated without repositioning of the volunteer nor the CSI grid at every time point in each volunteer. In total, 120 CSI data sets were acquired. An axial spin echo T2-weighted image (TR/TE= 3000/80 ms, slice/gap: 4/1 mm, TF: 10, FOV: 230 x 184 mm², matrix: 400 x 300) was acquired as a high resolution anatomical reference image , using automatic repositioning software provided by the vendor, in which the FOV was aligned along the anterior and posterior commissure on a 3D scout image. The CSI grid was manually positioned at two slices above the last slice in which the ventricles are noticed, symmetrically around the midline with the anterior margin of the field of view coinciding with the frontal skull (Figure 1). The CSI protocol had following imaging parameters: 2D PRESS, field of view (FOV): 16cm*16 cm, volume of interest (VOI): 8cm*8cm , slice thickness: 1cm, acquisition voxel size: 1cm*1cm, reconstruction voxel size: 0.5cm*0.5 cm, receiver bandwidth: 2000Hz, samples: 2048, number of signal averages: 1, water suppression method: MOIST, a train of four very selective pulses designed for B1 and water T1 insensitivity, a modification of the WET technique (3), shimming: pencil beam second order, parallel imaging with SENSE factor: left-right: 2 anterior-posterior: 1.8, 10 circular saturation bands in order to avoid lipid contamination from the skull. The acquisition time was 3 minutes, 30 seconds. To validate the reproducibility of the MRSI grid positioning, we analyzed the offset parameters of the MRSI plane (the off center vector, the angulations in the anterior-posterior, left-right and cranio-caudal plane) between the measurements at different time points within each volunteer. CSI data were checked upon quality as recommended in Kreis, 2004 (4). The spectra were preprocessed using MATLAB environment by water removal with HLSVD-PRO (5), baseline correction (6) and in-house normalization. In the 16*16 matrix of the VOI, the outer two lines from the bottom, the outer line from the top, two columns from the left and one column from the right were removed along the chemical shift displacement effect. The AQSES quantification method (7) in the remaining 13*13 matrix was used for fitting the 12 most representative metabolites (NAA, Glu, Cre, PCh, GPCh, Glc, Lac, Ala, Myo, Tau and Lips at 0.9 and 1.3ppm). In each voxel of the VOI the coefficient of variation (CoV) and the Cramer-Rao lower bounds (CRLB) were calculated for NAA, total Cho (tCho), Cre, Glx and Myo. Furthermore, an N-way-ANOVA analysis was performed with “scanner“ and “voxel position in the VOI” as fixed factors and with “healthy volunteer”, “immediate repetition” (repeatability), and “time point” as random factors. From the ANOVA analysis, η^2 values (i.e. proportion of variances), a measure of effect size, were calculated for each metabolite and each factor.

Results: The offset vector of the MRSI grid differed 0.55 +/- 0.13 mm between all 120 cases. The difference in angle between the line from the anterior to the posterior commissure and the transverse plane of the MRSI grid was less than 2° in all cases (anterior-posterior angulation: 0°, left-right angulation: 0.02° +/- 0.06°, cranio-caudal angulation: -0.38° +/- 0.88°). CSI data from one volunteer in one time point (two datasets) had to be rejected due to significant sideband artifacts. The CRLB for each voxel in the VOI in the 118 cases ranged (in percentage) from 2-18 % for NAA, from 20-55% for tCho, from 5-28% for Cre, from 20-100% for Myo and from 20-45% for Glx. Maps of CoV for the main metabolites in all voxels of the VOI averaged over all data sets are shown in figure 2. Although η^2 values vary among metabolites some trends can be deducted. $\eta^2_{repeatability}$ is less than 0.2% in all metabolites whereas $\eta^2_{interscanner}$ is less than 1% for all metabolites. $\eta^2_{intravolunteer}$ is less than 0.1% for all metabolites. $\eta^2_{intervolunteer}$ accounts for less than 2% (except for tCho, 6% and Myo, 10%). $\eta^2_{position}$ (difference due to voxel position in the VOI) and η^2_{random} (difference according to factors not accounted for, such as the inherent limitation of the quantification accuracy due to noise in the signals) account for the largest contributions in variability (28-68% and 31-60% resp.).

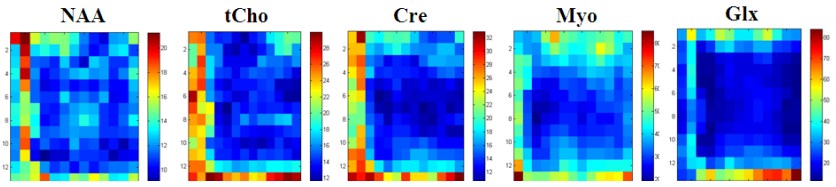

Fig. 2: maps of Cov of the 118 data sets for the respective metabolites

Conclusion: In this study, a reproducibility experiment was conducted to validate a rapid short echo time 2D MRSI acquisition protocol using the PRESS volume selection method. Furthermore, the robustness of vendor provided automated respositioning software for anatomical acquisitions was tested. Automated repositioning for anatomical sequences proved to be a very robust method which is of utmost importance in conducting longitudinal studies. Comparison of MRSI data acquisition on the same volunteers using different MR scanner indicates robust quantification, a pre-requisite for inter-institutional studies. However, great care should be taken for metabolite signals with low SNR (e.g. Myo) and in the regions of the chemical shift displacement which account for a substantial percentage of the VOI, an inherent drawback of the PRESS volume selection method.

References: (1) Bottomley PA (1987) Ann N Y Acad Sci / (2) Young et al., Proc. SPIE 2006 / (3) Ogg et al. (1994), J Magn Res /(4) Kreis (2004), NMR Biomed/ (5) Laudadio et al (2002), J. Magn. Res. / (6) Poullet et al. (2008), PhD thesis, Leuven / (7) Poullet et al (2007), NMR Biomed,