Absolute metabolite quantification in human brain using short echo-time CSI and a phased-array headcoil.

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Introduction. In contrast to single-voxel spectroscopy, it is not common practice to obtain absolute metabolite concentrations from chemical shift imaging (CSI), especially when data have been obtained with a receive-only phased-array headcoil. We implemented a method using the transmitter amplitude of the bodycoil, in combination with the ratio of the water-signal obtained from the bodycoil (SI_{body}) and the headcoil (SI_{head}) [1], applied to each CSI voxel separately. The method is demonstrated in a phantom containing 6 metabolites. Regional metabolite concentrations and age-related changes were investigated in a group of subjects between the age of 2 and 19 years.

Material and methods. A phantom with known concentrations of NAA, Cr, Cho, Ins, Glu, Lac (and Gd-DTPA for T_1-shortening) was scanned regularly for quality assurance. A total of 37 subjects with unremarkable conventional MRI and no significant abnormalities on neurological examination were included. Mild developmental delay, autism, and epilepsy were accepted. The subjects were divided into 3 age groups: 2-5y (n=15, 2.6 ± 0.8y), 5-10y (n=10, 6.8 ± 1.4y), and 10-19y (n=12, 13.0 ± 2.8y).
CSI measurements were performed at 1.5T (Siemens, Sonata, 8-channel phased-array headcoil), single 15 mm slice, FOV 160x160mm, 16x16 phase-encodings, PRESS localization VOI of 80x100mm, centered at NAA (2.7 ppm upfield from water), TR/TE 3000/30 ms, 6 averages with weighted phase-encoding, Hamming filter 50% (18min54s acquisition time). Unsuppressed water reference scans were obtained with both head- and bodycoil, 8x8 phase-encodings, interpolated to 16x16, TR/TE 1310/30 ms, 44s acquisition time each). The sequence included coherent summation of array-data followed by normalization [1], resulting in a single time-domain dataset. Eddy-current correction always improved the spectral quality of the phantom scans, and occasionally spectra of the subjects. Quantification used the voxel-wise ratio SI_{body}/SI_{head} and the transmitter amplitude of the bodycoil. Per subject spectra of six WM voxels (bilaterally frontal, semioval, and parietal) and 2 adjacent parietal GM voxels (Fig. 1) were quantified using LCModel [2]. SNR and FWHM (values in ppm from LCModel converted into Hz) were also obtained.

Results.
In the phantom metabolite concentrations were homogeneous in the central 40x60 mm of the VOI. The coefficient of variation (CoV) between these 24 voxels was ~7% using a mean ratio SI_{body}/SI_{head} from this area, which improved to <3% using a voxel-wise ratio. CoV between 16 scans (obtained over more than 1 year) was <3% for each of the 6 metabolite concentrations. Apart from the expected chemical shift displacement of the VOI for some metabolites, a small asymmetry (L > R, 5-10% difference when comparing columns 6 and 11) was observed mainly for Ins, Cho, and Glu, probably due to imperfect slice profiles [3].
Spectral quality in subjects was high (Fig. 1), with mean SNR around 19, and mean FWHM below 3 Hz. From the total of 296 spectra (37 subjects, 8 spectra each) only 11 spectra were discarded due to broad or distorted line shapes. In WM, with voxels typically located in columns 6 and 11, a small but significant left-right difference (using a paired t-test) was observed for Ins and Cho. However, a similar asymmetry for those metabolites was observed in the homogeneous phantom, showing the necessity of voxel-wise correction. After correction, no left-right differences remained, and concentrations of both hemispheres were averaged and listed in Table 1 and 2.
Observed metabolite concentrations were slightly smaller than those obtained with quantitative single-voxel STEAM [4], possibly due to effects of T1-relaxation during the shorter TR (3000 ms seems an upper limit for clinical CSI). Regional and age-variations were similar to previous observations [4-6]: concentrations of tCr, tNAA, Ins and Glu were higher in GM than in WM, whereas Cho was higher in WM. Both tCr and Cho showed a frontal-to-parietal decrease in WM. In the age-range currently examined only small changes were observed, such as an increase of tNAA and decrease of Cho in parietal WM (Table 2).

Fig. 1: selected voxels and parietal GM and WM spectra

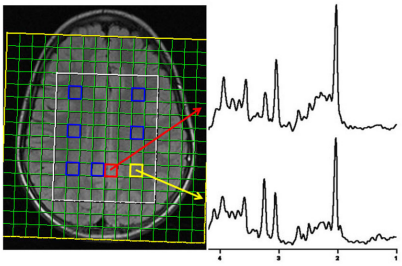

Table 1: regional variation (all subjects between 2-19y)

	WM frontal	WM semiovale	WM parietal	GM parietal
tNAA	6.9 ± 0.7	7.3 ± 0.8	6.8 ± 0.8	7.9 ± 0.9
tCr	4.5 ± 0.6	4.3 ± 0.5	3.8 ± 0.4	5.8 ± 0.6
Cho	1.61 ± 0.27	1.50 ± 0.24	1.42 ± 0.19	1.01 ± 0.16
Ins	3.2 ± 0.6	2.9 ± 0.5	3.1 ± 0.5	4.6 ± 0.6
Glu	5.7 ± 1.1	5.4 ± 1.0	4.8 ± 0.9	8.8 ± 1.1
Gln	2.8 ± 1.3	2.4 ± 1.1	2.1 ± 1.2	3.0 ± 1.1
SNR	19 ± 3	19 ± 3	19 ± 3	22 ± 3
FWHM / Hz	2.6 ± 0.8	2.6 ± 0.7	2.4 ± 0.6	2.2 ± 0.7

Table 2: age variation in parietal WM

# spectra	2-5 y n = 29	5-10 y n = 18	10-19 y n = 23
tNAA	6.5 ± 0.6	6.6 ± 0.7	7.4 ± 0.8
tCr	3.9 ± 0.5	3.7 ± 0.3	3.7 ± 0.4
Cho	1.48 ± 0.18	1.43 ± 0.23	1.32 ± 0.15
Ins	3.2 ± 0.6	3.1 ± 0.5	3.1 ± 0.4
Glu	5.1 ± 0.9	4.5 ± 1.0	4.5 ± 0.6
Gln	2.1 ± 1.0	1.8 ± 1.1	2.4 ± 1.2
SNR	21 ± 3	19 ± 3	17 ± 2
FWHM / Hz	2.2 ± 0.6	2.4 ± 0.7	2.7 ± 0.6

Discussion and Conclusions.
This study has shown that quantitative metabolite concentrations can reliably be obtained with CSI and a phased-array head-coil, using a carefully designed protocol. High spectral quality in adjacent voxels may help the quantitative analysis at high spatial resolution of diseases where small but significant metabolic changes can occur in small regions of the brain, such as in childhood white matter disorders or MS.

References [1] Natt - MRM 2005;53:3-8. [3] Lundbom - AJNR 2005; 26:1072-7. [5] McLean - MRM 2000;44:401-11.
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