Extended metabolite profile of the human spinal cord

Andreas Hock[1], Bertram Wilm[1], Erin L. MacMillan[2], Roland Kreis[2], Spyros S Kollias[3], Peter Boesiger[1], and Anke Henning[1,4]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Dept. of Clinical Research and Institute of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Bern, Switzerland, [3]Institute of Neuroradiology, University Hospital of Zurich, Zurich, Switzerland, [4]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Introduction: Magnetic resonance spectroscopy (MRS) is rarely applied in spinal cord due to technical challenges, including strong susceptibility changes in this region and the small diameter of the myelon, which limit the attainable SNR and lead to lineshape distortions (1). Therefore, reliable detection (Cramér–Rao lower bounds (CRLB) < 20) was reported for only four metabolites (NAA, Cr, Cho and mI) (1,2). A detection of further metabolites would improve the clinical value of MRS. As shown previously, non-water-suppressed MRS via the metabolite cycling (MC) technique (3) enables frequency alignment of every FID even with the very low SNR available in the human spinal cord, improving the spectral quality of related MRS measurements. However, the sensitivity of the method is still limited by the low SNR obtained. To overcome this problem, we tested two different approaches: 1.) MC is used together with a very high number of averages and 2.) MC is used in combination with a dedicated three element neck array coil.

Methods: ECG-triggered, higher order, projection-based B_0 shimming (4), ECG-triggered PRESS localization combined with inner-volume saturation and the MC technique (3) (3 T Achieva, Philips Healthcare, Best, TE/TR = 30/2000 ms, voxel size = 1.2 ml) was performed at the cervical level C3-4 (figure 1 A). One female volunteer was measured four times within one month with a standard NeuroVascular coil (Philips Healthcare, Best). Each measurement comprised 512 FIDs, thus a total number of 2048 FIDs was available for averaging. A second female volunteer was measured with a dedicated, home-built, three element coil array, placed close to the neck (figure 1 B), with the same protocol and with 512 FIDs. All MRS data were quantified using LCModel (5).

Results: The LCModel fit of the four spectra (512 FIDs each) from the same volunteer and the averaged spectra including 2048 FIDs is shown in figure 1 C-I. In addition, the LCModel fit of the spectrum acquired with the dedicated neck coil is shown (figure 1 J). Table 1 shows the quantification results, the SNR, and the full width at half maximum (FWHM) of the unsuppressed water peak of the spectra.

Discussion: MC as used in (3) allows for frequency alignment of single FIDs offering the possibility to gain SNR by constructive averaging of 2048 FIDs without a substantial increase in line width of the spectra. The high spectral quality allows the investigation of an extended spectral fingerprint of the human spinal cord. However, the scan time would be too long for a single scan session. An alternative way to increase SNR even further while maintaining the original number of 512 FIDs, feasible to acquire in one scan session, was found by using a closely fitting neck coil array. Thereby a reliable detection of total N-acetyl aspartate (NAA), total creatine (Cr), total choline (Cho), myo-inositol (mI), and scyllo-inositol (sI) was possible at 3T. In addition, glutamine and glutamate (Glx) could be identified reliably (CRLB $\leq$ 20). Furthermore, because of the high SNR obtainable with the three element neck coil glutathione (GSH) with CRLB of 25% and aspartate (Asp) with CRLB of 26% might be additionally detectable markers. By comparing the results with brain estimates increased mI/Cr and sI/Cr can be observed (Table 1). In addition, Asp/Cr is potentially increased. The reason for the altered metabolite profile in the spinal cord might be the different tissue composition and physiology. Because of the lack of a gold standard for *in vivo* metabolite quantification in the spinal cord, post-mortem *ex vivo* measurements might be used for validation of these findings in the future.

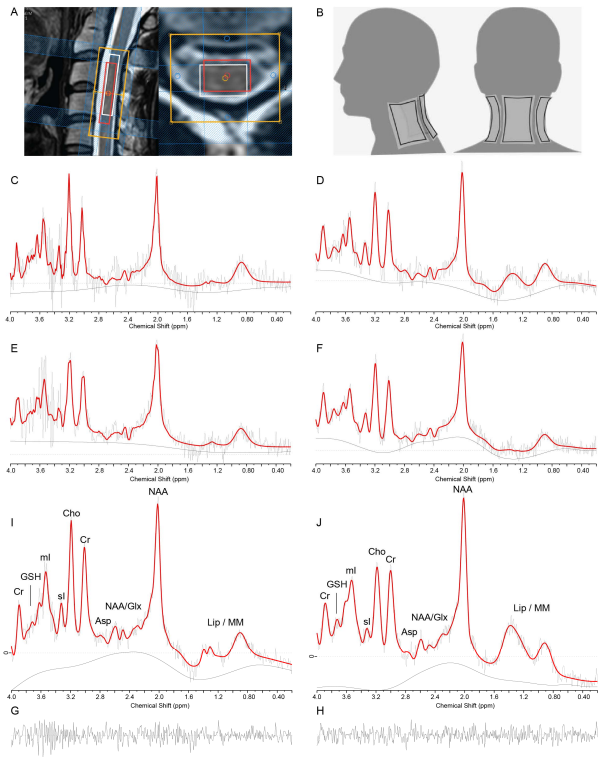

Figure 1: *(A) Localization images, (B) placement of the home-built neck coil, spectra and LCModel fit of the 4 acquisitions with 512 FIDs (C-F), of 2048 FIDs (I), and of the 512 FIDs acquired with the dedicated neck coil (J). In addition, the residuals of I & J are shown (G & H).*

Acknowledgements: Thanks to Bertram J. Wilm, Nicola De Zanche, Jurek Massner, and Klaas P. Prüssmann for providing the custom built neck coil.

References:

1. Henning A. et al.,. Magn Reson Med 2008;59(6):1250-1258.
2. Marliani A. F. et al.,. Magn Reson Med 2007;57(1):160-163.
3. Hock A. et al.,. Magn Reson Med 2012.
4. Hock A. et al.,. NMR Biomed 2012;Epub ahead of print.
5. Provencher S. W. Magn Reson Med 1993;30(6):672-679.
6. Govindaraju V. et al.,. NMR in Biomedicine 2000;13(3):129-153.

Table 1: Quantification results. Note: Values with CRLB <20% are displayed in blue, 20%-30% in green, and >30% in red. In addition, brain concentration over Cr ratios are calculated based on the results presented by Govindaraju et al.(6) for comparison, but should be used with caution, as they include a range of different brain areas, techniques, and conditions.

	SNR (mean ± SD), **FWHM (Hz)** (mean ± SD)	**tNAA/Cr** (mean ± SD, mean CRLB)	**tCho/Cr** (mean ± SD, mean CRLB)	**mI/Cr** (mean ± SD, mean CRLB)	**sI/Cr** (mean ± SD, mean CRLB)	**Glx/Cr** (mean ± SD, mean CRLB)	**GSH/Cr** (mean ± SD, mean CRLB)	**Asp/Cr** (mean ± SD, mean CRLB)
512 FIDs, (n=4)	8 ± 2, 6± 1	1.2±0.1, 8%±1.8%	0.4±0.1, 7%±0.8%	2.6±0.4, 8%±0%	0.3±0.04, 13%±0.6%	2.1±0.3, 23%±1.5%	0.2±0.1, 54%±30%	0.4±0.1, 53%±13%
2048 FIDs, (n=1)	12, 7	1.1, 8%	0.4, 8%	2.8, 8%	0.3, 16%	1.9, 20%	0.1, 96%	0.5, 34%
Home-built neck coil(n=1)	14, 9	1.0, 8%	0.4, 9%	2.6, 7%	0.3, 11%	1.8, 14%	0.4, 25%	0.5, 26%
Brain Cr ratios derived from (6), (min-max)		0.8-3.78	0.08-0.49	0.36-1.59	0.03-0.12	0.85-3.59	0.19-0.39	0.09-0.27