Spinal cord MR spectroscopy in neoplastic lesions

Andreas Hock[1], Fuchs Alexander[1], Peter Boesiger[1], Anke Henning[1], and Spyros S. Kollias[2]
[1]*University and ETH Zurich, Institute for Biomedical Engineering, Zurich, Switzerland,* [2]*Institute of Neuroradiology, University Hospital of Zurich, Zurich, Switzerland*

Introduction: Single voxel ^{1}H magnetic resonance spectroscopy (MRS) provides information about biochemical processes of neuronal tissue which is complementary to conventional MRI investigations. Metabolite concentrations reflect the state of energy metabolism, myelination, neuronal density and function, glial impairments or altered membrane turnover, which is highly valuable for the investigation of spinal cord pathologies. Of specific interest is the non-invasive differentiation between low grade neoplasia and demyelination in order to prevent unnecessary biopsies and surgeries thus avoiding a negative impact on patient outcome. However, data quality of ^{1}H MRS acquisitions in the spinal cord suffer from limited signal to noise ratio (SNR) and lineshape distortions due to technical challenges, including strong susceptibility changes around and the finite size and deep location of the cord. In addition, patient motion hinders the acquisition. **In this work,** a protocol for spinal cord MRS was developed allowing robust and high quality spinal cord acquisitions to determine specific changes in the metabolite fingerprint of tumor patients compared to controls and patients suffering from multiple sclerosis (MS).

Materials and Methods: After approval from the local ethics committee 13 healthy volunteers, 13 patients suffering from MS and three patients with neoplastic spinal cord lesions were involved in the study: one Ependimoma (WHO II), one Schwanoma (WHO II) and one low grade tumor that was not specified by biopsy. The latter patient was measured twice at baseline and after two months. All MR experiments were performed on a Philips Achieva 3T scanner (Philips Healthcare, Best, the Netherlands) using the integrated body-coil (maximum B1=13.5 µT) for transmission and a Philips SENSE Neurovascular coil for reception (ring of 4 neck coils). ECG-triggered, inner-volume saturated PRESS localization (1) (TE=30 ms, TR=2 heart beats) was used to acquire single voxel spectra of the spinal cord. Six inner-volume suppression (IVS) bands (1,2) were applied to minimize the chemical shift displacement artefact and to reduce the influence of pulsatile flow of the cerebrospinal fluid. A VAPOR water suppression scheme interleaved with IVS (3) was used instead of CHESS water suppression prior to IVS (1,4,5) to further reduce the residual water. Second order ECG-triggered FASTERMAP shimming (6) was performed to compensate for B_0 inhomogeneity. MRS acquisition consisting of 512 FIDs was split into four blocks of 128 FIDs to be able to check the voxel position by acquiring axial T2-weighted images after each block. If patient motion was identified, the voxel position was updated for the next block of 128 FIDs and the measurement was repeated. Prior each block 16 non-water-suppressed scans were acquired for frequency, phase and eddy current correction. MRS data were quantified using LCModel (7) as described in more detail previously (1).

Results and Discussion: The described measurement protocol enables robust (no measurement had to be excluded due to technical problems e.g. bad shim convergence) recordings of high quality as shown in Fig. 1 (zero filled and 4 Hz Gaussian filtered). In addition, low Cramér–Rao lower bounds (CRLB) shown together with the quantification results in table 1 indicate a sufficient quantification reliability. In contrast to controls (Fig. 1 F) spectra measured in different pathologies (Fig. 1 A-E) in the spinal cord show a distinct change in the metabolite fingerprint with high correlation to connatural MRS acquisitions in the brain. Spectra measured in patients suffering from MS show an increase in the normal appearing white matter of myo-Inositol (mI) / creatine (Cr) and choline (Cho) / Cr and a decrease in N-acetyl-aspartate (NAA) / Cr. This trend was also reported by Marliani et al. (8) in MS lesions. The extradural tumor (Schwanoma) shown in Fig. 1 C does not contain any brain metabolite in contrast to the Ependimoma showing strongly reduced NAA / Cr, increased Cho / Cr and strongly increased mI / Cr in addition to lipids (Lip) respectively Lactate (lac) compared to controls. The two spectra of the not specified tumor (Fig. 1 A & B and the last two lines in table 1) showing also strongly reduced NAA / Cr, increased Cho / Cr and increased mI / Cr resemble each other supporting the reproducibility of the technique.

In conclusion, ECG-triggered VAPOR water suppressed ^{1}H MRS in the spinal cord enables a reliable metabolite quantification and holds potential for differential diagnostics of various neuropathologies.

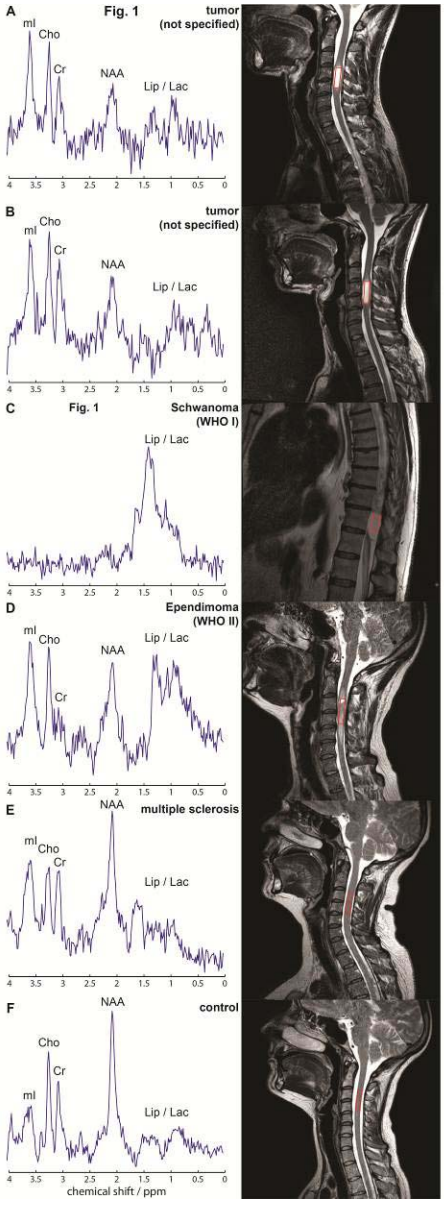

Table 1: Metabolite ratios. Increased values compared to controls are marked red; decreased values are marked blue.

subjects	**NAA/Cr** (mean ± SD, mean CRLB)	**Cho/Cr** (mean ± SD, mean CRLB)	**mI/Cr** (mean ± SD, mean CRLB)
Controls, n=13, C 3-4	1.6 ± 0.3, 8 %	0.43 ± 0.1, 12 %	2.9 ± 0.41, 8 %
MS, n=13, C 3-4, normal appearing WM	1.3 ± 0.4, 14 %	0.47 ± 0.11, 11 %	3.58 ± 0.65, 9 %
Ependymoma (WHO II), n=1, C 3-4	1.3 ± -, 35 %	1.48 ± -, 15 %	12.8 ± -, 11 %
Schwanoma (WHO II), n=1, Th 11	- ± -, -	- ± -, -	- ± -, -
Tumor (not specified), n=1, C 4-5	0.67 ± -, 28 %	0.54 ± -, 9 %	3.76 ± -, 8 %
Tumor (not specified), n=1, C 4-5	0.51 ± -, 36 %	0.56 ± -, 10 %	4.66 ± -, 7 %

References:
1. Henning A. et al., Magn Reson Med 2008;59(6):1250-1258.
2. Schulte R. F. et al., Journal of Magnetic Resonance 2007;186(2):167-175.
3. Henning A. et al., NMR Biomed 2009;22(7):683-696.
4. Cooke F. J. et al., Magn Reson Med 2004;51(6):1122-1128.
5. Marliani A. F. et al., Magn Reson Med 2007;57(1):160-163.
6. Hock A. et al., Proc Intl Soc Mag Reson Med 2010 2010;5042.
7. Provencher S. W. Magn Reson Med 1993;30(6):672-679.
8. Marliani A. F. et al.,.AJNR Am J Neuroradiol 2010;31(1):180-184.