In-vivo proton MR spectroscopic imaging of the human brain gliomas at 9.4 Tesla: evaluation of metabolite coordinates

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Purpose: Recently it was demonstrated that the advantages of ultra-high field MR spectroscopic imaging (MRSI), namely the better signal-to-noise ratio and the improved spectral resolution, can be useful in clinical applications[1]. Clinical studies conducted at field strengths below 3T have shown that an evaluation based on the Orthonormal Discriminant Vector method (ODV) enables differentiation between low (WHO grade II and III) and high grade (WHO grade IV) human brain tumors[2, 3]. The aim of this study was to verify the usefulness of the ODV method in assessing human brain tumor spectra measured with MRSI at a field strength of 9.4T.

Methods: MRSI spectra were acquired with a 9.4T whole body scanner (Siemens, Erlangen, Germany) using a custom-built 16 channel transmit/ 31 channel receive coil[4]. A modified STEAM[5] sequence was used for data acquisition (TE: 20 ms, TM: 11, TR: 2000 ms, spectral bandwidth 4 kHz, voxel size 10 mm isotropic). The 3.1 kHz bandwidth of the hermite excitation pulses resulted in a chemical shift displacement of 39%. MRSI was planned on gradient echo (GRE) images (TR: 302 ms, TE: 9 ms, flip angle: 25°, voxel size: 0.6 × 0.6 × 2 mm^3) and the flip angle of the STEAM pulses was calibrated with an actual flip angle mapping (AFI) sequence (TR1: 20 ms, TR2: 100 ms, TE1 and TE2: 7 ms, nominal flip angle 60°, voxel size 4.2 × 2.1 × 5 mm^3). Post-processing consisted of zerofilling to 4096 data points and manual phase and offset correction. The ODV method[2, 3] was used for spectral evaluation. It consists of calculating metabolite coordinates (ODV1 and ODV2), based on a weighted linear combination of ratios between the metabolite integrals (inositol- Ins, glutamine- Gln, glutamate- Glu, N-acetylaspartate- NAA, total choline- tCho and lactate- Lac) and the integral of the total Creatine peak (tCr), and allows to simplify the entire spectrum to a single point on a 2-D plane. Post-processing and evaluation were done offline with the use of custom-written Matlab routines. A group of 8 patients (4 with grade II and 4 with grade III brain tumors) underwent MR examination with approval by the local ethics board.

Results: Fig. 1 shows the results of the ODV analysis, where the separation between the points representing healthy (black) and tumor (blue and red) spectra is clearly visible. Additionally, most points associated with the tumor spectra form two groups, improving the separation between WHO grade II (blue) and grade III tumors (red). This can be explained by a direct comparison of healthy (2a) and tumor (2b-c) spectra seen in Fig. 2. With respect to healthy tissue (2a, black), grade II (2b, blue) and grade III (2c, red) tumors show a typical pattern with increased signals of tCho and Ins, and decreased NAA. Additionally, both kinds of tumors have increased Gln and taurine (Tau) and decreased Glu. A comparison of both tumor spectra reveals that tCho, Gln and Tau are increased further and NAA is decreased in the grade III tumor spectrum (2c).

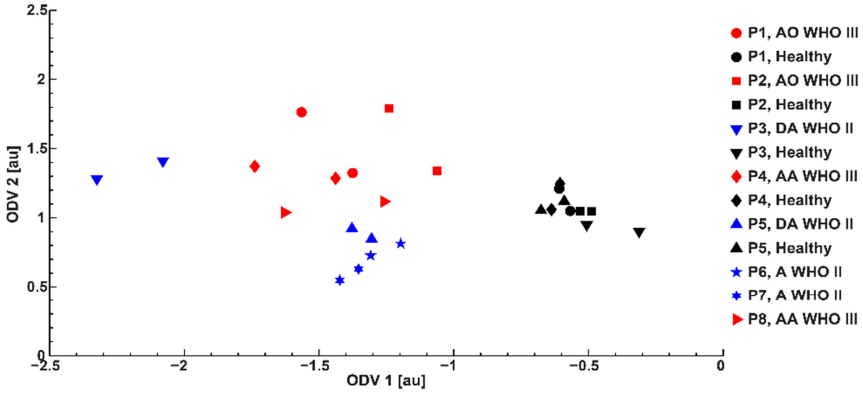

Fig.1: ODV coordinates calculated from healthy (black) and tumor spectra (grade II- blue, grade III- red). Abbreviations used: AO- anaplastic oligoastrocytoma, DA- diffuse astrocytoma, AA- anaplastic astrocytoma, A- astrocytoma.

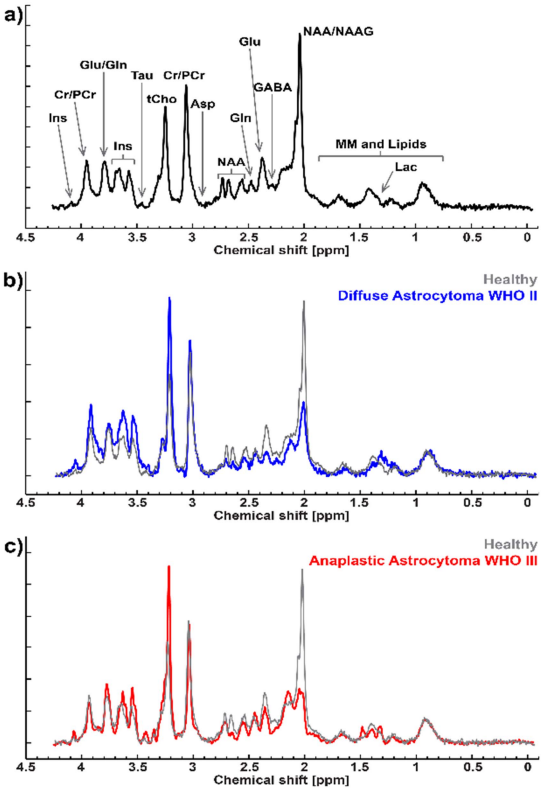

Fig.2: Example of a healthy (a) and tumor (b-c) spectra. In order to facilitate the comparison, tumor (color) and healthy (gray) spectra (b, c) are overlapped, after scaling to the reference metabolite (tCr).

Discussion/Conclusions: It was demonstrated that the ODV method, primarily developed for magnetic fields lower than 3T, can be successfully applied for analyzing in-vivo spectra acquired at 9.4 T, where it not only shows a clear separation between healthy and tumor spectra, but also offers the possibility to distinguish between grade II and III tumors (Fig. 1), which at lower field strengths was not possible[2, 3]. This is mainly due to the fact that the enhanced spectral resolution at ultra-high fields allows for better separation between overlapping resonances (especially Glu and Gln), which have a strong influence on the metabolite coordinates calculated with ODV. Further improvements in differentiation between grade II and III brain tumors could be achieved by using the output from the LCModel to calculate the ODV metabolite coordinates and by recalculating the ODV weights to emphasize metabolites relevant for tumor grading. In summary, thanks to the increased spectral resolution, the ODV method, when applied to tumor spectra acquired at 9.4T, can facilitate tumor assessment and thus may have high potential for clinical applications.

References: 1. Chadzynski GL, et al. ISMRM 2013, #961; 2. Hagberg G, et al. Magn Reson Med 34:242-252 (1995); 3. Roser W, et al. Magn Reson Mater Phys 5:179-183 (1997). 4. Shajan G, et al. Magn Reson Med 71:870-879 (2013); 5. Chadzynski GL, et al. Magn Reson Mater Phys DOI: 10.1007/s10334-014-0460-5 (2014).