FIRST PROTON CSI OF A HUMAN BRAIN TUMOR AT 9.4T

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Introduction: Recent studies have shown that in-vivo proton chemical shift imaging (1H CSI) at ultra-high magnetic field may benefit from the gain in signal to noise ratio and spectral resolution [1, 2]. This could be of interest when assessing the physiopathology of brain tumors, where detection of 2-hydroxyglutarate (2HG) with 1H CSI at a field strength of 3 T has recently been reported [3]. This particular compound is associated with mutations in isocitrate dehydrogenasis (IDH) frequently occurring in grade 2 and grade 3 gliomas [3]. The aim of this study was to verify whether proton CSI at a field strength of 9.4 T can facilitate the diagnosis of human brain tumors.

Materials and Methods: CSI spectra were acquired at 9.4 T whole body scanner (Siemens, Erlangen, Germany) equipped with a home-build 16 channel transmit coil [4] combined with a 31 channel receiving helmet [5]. A stimulated acquisition mode sequence (STEAM) was used for data acquisition (TE: 20 ms, TM: 11 ms, TR: 2000ms, spectral bandwidth 4000 Hz, voxel size 10 mm^3 isotropic). Four outer volume suppression slabs placed parallel to the edges of volume of interest (VOI) minimized the contamination of acquired spectra with unwanted signal from outside of VOI. Due to hardware limitations, the standard h-sinc RF pulses in the STEAM sequence were replaced with hermite RF pulses. The influence of the chemical shift displacement was minimized by shortening the duration of the RF pulses, which allowed increasing the RF bandwidth from 1650 to 3100 Hz. To determine the correct value of the flip angle, the CSI acquisition was preceded by the actual flip angle mapping (AFI) sequence (TR1: 20 ms, TR2: 100 ms, TE1 and TE2:7 ms, flip angle: 60°, voxel size: 4.2x2.1x5 mm^3). Gradient echo (GRE) images (TR: 302 ms, TE: 9 ms, flip angle: 25°, voxel size: 0.6x0.6x2 mm^3) were used as anatomical reference and for positioning the VOI. A 44 years old patient with clinically confirmed oligodendrogioma with IDH mutation underwent the MR examination. The measurements were approved by the local ethical committee.

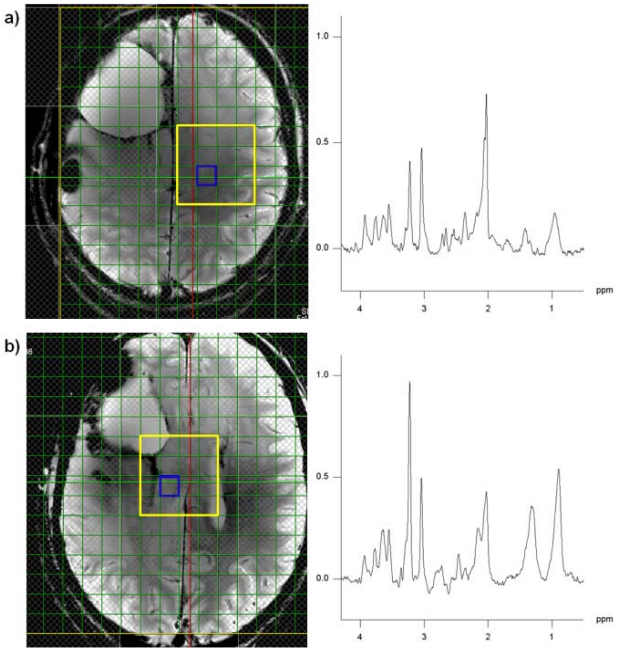

Fig 1: Gradient-echo scout images and spectra examples acquired in healthy tissue (a) and tumor area (b).

Results: Fig. 1 shows the GRE scout images and spectra measured in the healthy tissue (a) and within the tumor (b). It can be seen that a large part of the tumor has already been removed. Exact delineation of the post-operative tumor mass was hampered due to poor tumor-to-tissue contrast. The approximate tumor mass center was located in the cingulate cortex of the right hemisphere, just above the body of the corpus callosum, and extended towards the frontal horn of the lateral ventricles. The VOI for the CSI measurements was placed in the healthy tissue (Fig. 1a) and in the center of the tumor (Fig. 1b). Spectra acquired from both locations are depicted on the left side of Fig. 1. Those were analyzed with the LCModel software [6], which revealed the presence of 2HG in the tumor spectrum (fitted with Cramer-Rao lower bound, CRLB < 14%). Further investigation of metabolite levels in both spectra showed that in the tumor tissue the levels of aspartate (Asp), N-acetylaspartate (NAA), N-acetylaspartylglutamate (NAAG) and glutamate (Glu) are significantly decreased, whereas glutamine (Glu), myo-inositol (Ins), scyllo-inositol (Scyllo) and taurine (Tau) are increased.

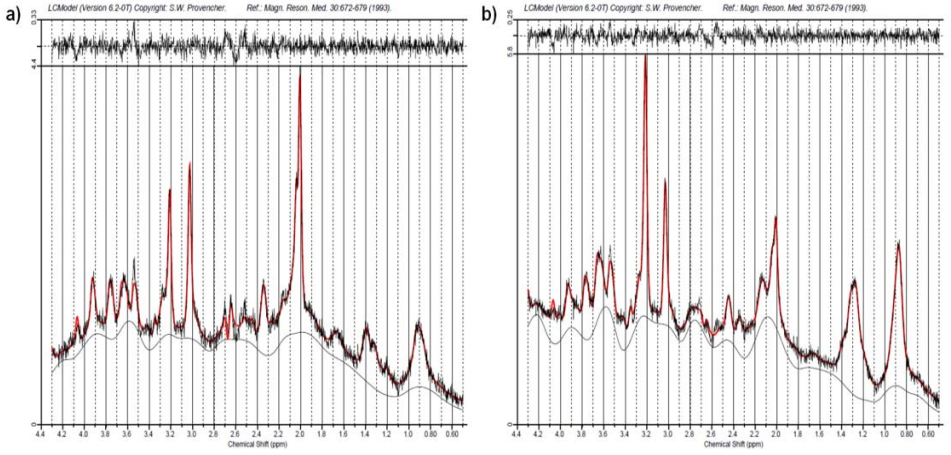

Fig 2: Results of quantification with LCModel software. Displayed are: spectrum from healthy tissue (a) and from tumor (b).

Discussion/Conclusions: We have demonstrated that, due to improved signal-to-noise ratio and spectral resolution, CSI at ultra-high field offers a better insight in the pathological processes in the human brain. Spectra presented here show good quality. It was possible to detect 14 metabolites with CRLB lesser than 20%, including the 2HG, which has a potential to be a diagnostic and prognostic biomarker in brain tumors [1]. We did not, however, perform an absolute quantification, because this would require increasing the TR to at least 8 s, which would drastically prolong the total scanning time. In this particular case, we were able to verify the presence of 2-HG in the tumor tissue, which was already confirmed by a histopathological examination. As demonstrated in the recent study conducted at a field strength of 3 T [1], further improvement in detection of 2-HG could be realized by a numerical optimization of the sequence. According to our knowledge this is the world's first report of a clinical examination conducted at a field strength of 9.4 T. In summary, due to increased sensitivity in detecting a larger number of metabolites, CSI at ultra-high fields has a great potential for clinical applications.

References: [1] Avdievich NI, et al. Magn Reson Med 62:17-25 (2009); [2] Deelchand DK, et al. J Magn Reson 206:74-80 (2010), [3] Choi C, et al. Nat Med 18:624-630 (2012), [4] G. Shajan, et al. ISMRM 2012, #308, [5] G. Shajan, et al. ESMRMB 2012, #351, [6] Provencher S, et al. Magn Reson Med 30:672-679 (1993).