Diffusion-weighted 1H NMR Single Voxel Spectroscopy at 3T and 7T

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Introduction: Although diffusion-weighted imaging detecting changes of the diffusion coefficient (ADC) of water protons is well established in the diagnosis of metabolic pathologies such as brain infarcts, only few reports exist on the diffusion behaviour of brain metabolites [e.g. 1-7]. As Single Voxel Spectroscopy (SVS) at high and ultra high fields is expected to lead to increased signal-to-noise ratio and spectral resolution, diffusion-weighted spectroscopy (DW-SVS) may lead to new insights how spatially resolved metabolite maps change under different metabolic conditions. However, due to the lower ADC values of the metabolites [7], higher b-values are necessary. Since diffusion weighting decreases the SNR, an initial high signal such as provided by high field systems is advantageous. We therefore implemented DW-SVS on a 3T- and 7T-MR-Scanner. In phantom studies, this allowed the calculation of the ADC values of several brain metabolites.

Methods and Materials: The measurements were performed on two whole-body scanners with 3T and 7T (Siemens, Erlangen, Germany) with 8-channel phase array coils (Siemens, Erlangen, Germany [3T] and RAPID, Würzburg, Germany, [7T]). The sequence was implemented in IDEA VA25 for the 3T and IDEA VB 12 for the 7T. Based on a SVS STEAM-Sequence additional diffusion-weighting gradients were implemented that could be applied separately or combined in each direction. DW-Gradients were inserted before the first and after the second TE-Crusher; with varying gradient field strength up to 25 mT/m, duration of 16.0 ms and a constant mixing time of 90.0 ms. Additional imaging parameters: voxel size 2.0 x 2.0 x 2.0 cm³, TE=136 ms, TR=1500 ms, 64 averages, spectral width 2 kHz for 3T and 10 kHz or 7T, vector-size: 1024, zero-filling to 2048, b-values: 0 – 3600 s/mm² (all gradients applied simultaneously). In vitro determination of the ADC values was performed with a spectroscopy phantom (General Electric, Braino-Phantom) containing among others NAA, creatine, myo-inositol and choline chloride.

Results and discussion: The spectra on both scanners exhibited an excellent spectral resolution and a good signal-to-noise ratio (fig. 1). Diffusion-weighting was evaluated by determining the ADC values of the water protons in the phantom (1) for 3T to (2.45 ± 0.08) x 10^{-3} mm²/s, and for 7T to (2.26 ± 0.15) x 10^{-3} mm²/s. The ADC values for the metabolites were determined taking the logarithm of the relative signals as a function of the b-values (fig. 2). The ADC were: (1) for 3T to (0.81 ± 0.15) x 10^{-3} mm²/s for NAA and (0.902 ± 0.094) x 10^{-3} mm²/s for creatine; (2) for 7T to (0.103 ± 0.151) x 10^{-3} mm²/s for NAA and to (1.26 ± 0.129) x 10^{-3} mm²/s for creatine. Within the experimental errors the ADC values agree well between both scanners and with published values (all measured with a temperature of 20°C) of water (2.14 ± 0.05) x 10^{-3} mm²/s, NAA (0.82 – 0.88) x 10^{-3} mm²/s, and creatine (0.8 ± 0.05) x 10^{-3} mm²/s [4].

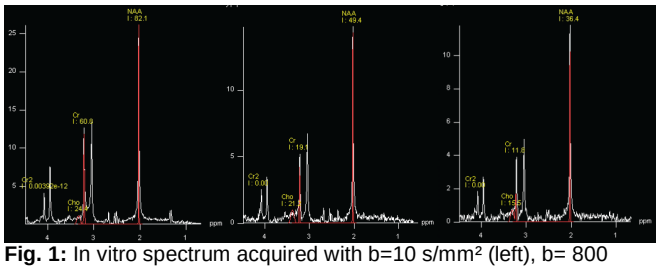

Fig. 1: In vitro spectrum acquired with b=10 s/mm² (left), b= 800 s/mm² (middle) and b=1400 s/mm² (right) at the 7T scanner.

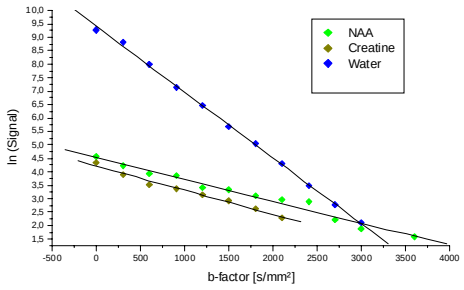

Fig. 2a: Logarithm of the signal of water, NAA and creatine depending on the b-value (3T, in vitro)

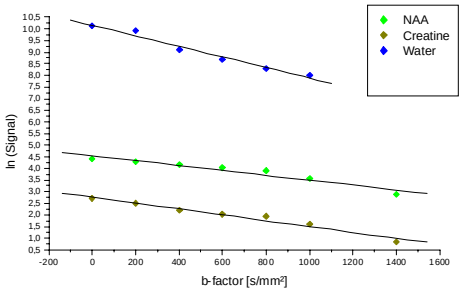

Fig. 2b: Logarithm of the signal of water, NAA and creatine depending on the b-value (7T, in vitro)

Conclusion: SVS-STEAM sequences could be successfully implemented with additional diffusion-weighting gradients at 3T and 7T systems. To the best of our knowledge this is the first diffusion-weighted SVS study on a whole body 7T scanner. The method is now being optimized and used for measurements on healthy volunteers and secondarily on patients with brain pathologies.

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