2D Diffusion Weighted Chemical Shift Imaging of Brain Metabolites at 7T

A. Techawiboonwong[1], H. Kan[2], M. Versluis[2], A. Webb[2], and I. Ronen[2]
[1]Electrical Engineering, Mahidol University, Puttamonton, Nakornpathom, Thailand, [2]C.J. Gorter Center for High Field MRI, Radiology, Leiden University Medical Center, Netherlands

Introduction: Diffusion-weighted and diffusion tensor spectroscopy (DWS, DTS) of brain metabolites such as N-acetyl aspartate (NAA), creatine and choline have been shown capable of providing microstructural information that is specific to compartmental geometry in which they reside [1-4]. So far, all DWS and DTS studies have been performed as single volume (SV) scans where accurate calculations of metabolite diffusion properties such as an apparent diffusion coefficient (ADC) and fractional anisotropy (FA) require proper phasing of individual spectra prior to averaging to avoid destructive signal summation. Here, we present, for the first time, a complete 2D-DW-CSI experiment of human brain metabolites. The introduction of a navigator used to remove the phase fluctuations caused by the diffusion gradients allows one to obtain spatially correct DW CSI data sets, and therefore calculate reliable ADC maps for several metabolites from an entire slice.

Materials and Methods: All experiments were performed on a 7T scanner (Philips Achieva^{TM}) equipped with a 16-channel multi-receive coil and a transmit head coil (Nova Medical Inc., Wilmington, MA, USA). Data were obtained from a 48-yo male healthy volunteer with the following scan parameters: TR 2500ms, TE 95ms, TM 150ms, VOI 85x120mm^2, readout bandwidth 3kHz, 2048 sample points, matrix size 14x14 and voxel size 16x16x15mm^3. Diffusion weighting was applied in six standard non-colinear diffusion directions with g=1.7g/cm, Δ=195ms and δ=25ms, resulting in b=4862 s/mm^2. One set of data was also collected without diffusion (b=0). Our STEAM-based 2D-DW-CSI pulse sequence is shown in Figure 1. The bipolar diffusion gradient scheme was employed here to minimize Eddy-current effects [5]. The phase-encoding gradients were moved to just before signal acquisition. Navigator data was then collected preceding the echo acquisition to obtain the phase information prior to the phase-encoding step. Navigator data was obtained for 30 points and zero-filled to 64 points, then Fourier transformed (FT). The FT of navigator for each phase encoding step yielded a coarse spectrum (0.156 ppm per point) in which, thanks to the high SNR at 7T, the NAA peak could be easily identified and used for phase measurement and correction for the corresponded phase-encoded signals.

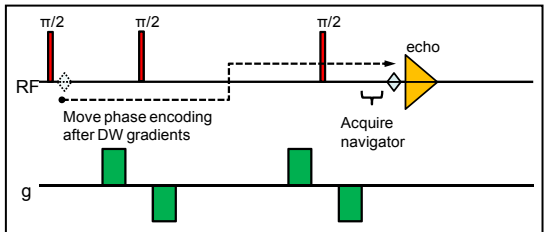

Fig.1 STEAM-based 2D-DW-CSI sequence diagram

Results and Conclusions: Spectra of the 64-point navigator from 196 encoding steps for diffusion direction #6 are shown in Figure 2. The spectra illustrate sufficient NAA signal levels for the subsequent phasing process. The proper phasing has been demonstrated to be crucial in Figure 3, where the spatial distributions of the NAA in the DW-CSI maps without phase-corrections (bottom row) are corrupted by the phase fluctuations, and efficiently recovered with the aid of the navigator scheme (top row). The 2D ADC maps were calculated for the phase-corrected and non-phase-corrected data as shown in Figure 3e and f, respectively. ADC values in GM and WM voxels (gray and white boxes in Fig 3e) were 1.4x10^{-4} mm^2/s and 2.0x10^{-4} mm^2/s, in accordance with prior SV-DWS results. RF field inhomogeneity from a volume transmit coil caused large SNR variations in the large VOI. Thus, measurements in such areas (the lower left corner of the 2D maps) may be inaccurate and were excluded from the analysis.

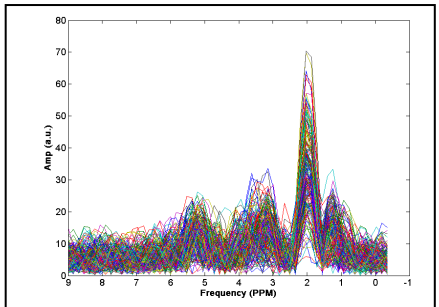

Fig.2 Navigator spectra for diffusion dir #6

Our work demonstrated the feasibility of obtaining 2D maps of human brain metabolites' diffusion properties at 7T. Further improvements of technique include accelerated acquisition (e.g. PEPSI) to make the scan time suitable for clinical imaging, as well as for DTS of NAA and other metabolites (not shown here).

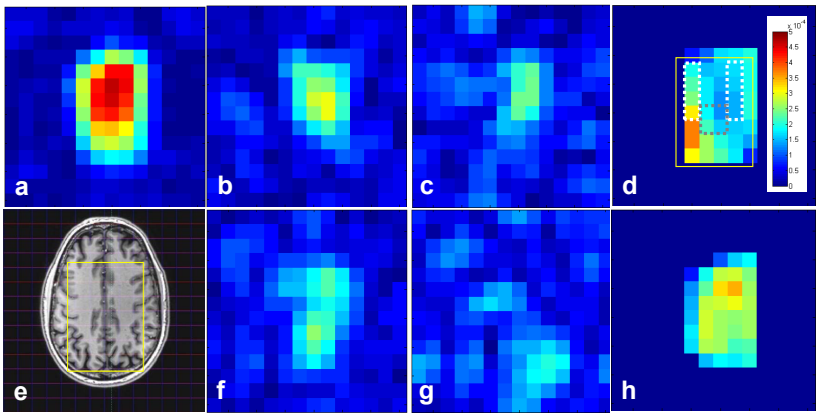

Fig.3 2D maps of NAA signal amplitudes a) without diffusion; b-c) for diffusion directions 1 and 6; f-g) for the same diffusion directions without phase-correction; d) the ADC map of NAA masked to the scanned VOI (yellow box); h) the map without phase-correction; e) the corresponded anatomical image.

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