Fast 3D proton MR spectroscopic imaging of the human brain *in vivo* at 7 Tesla using "spectroscopic Missing Pulse – SSFP": First results

C. Schuster[1,2], W. Dreher[1,2], J. Stadler[3], J. Bernarding[4], and D. Leibfritz[1,2]

[1]University of Bremen, FB 2 (Chemistry), Bremen, Germany, [2]Center of Advanced Imaging (CAI), Bremen, Germany, [3]Leibniz Institute for Neurobiology, Magdeburg, Germany, [4]Institute for Biometry and Medical Informatics, University Hospital of Magdeburg, Magdeburg, Germany

Introduction

Fast 3D proton MR spectroscopic imaging (^{1}H MRSI) of the human brain *in vivo* at 3 Tesla using SSFP based sequences like spectroscopic CE-FAST [1] and spectroscopic Missing Pulse - SSFP [2] (spMP-SSFP) provides rapidly acquired maps of the distribution of human brain metabolites. Moving towards higher static magnetic fields, SSFP based sequences are even more advantageous because of two reasons: i) the spectral resolution will be higher and/or ii) the repetition time (TR) can be shorter for a given spectral resolution resulting in a shorter minimum total measurement time and a higher signal-to-noise ratio per unit measurement time (SNR_t) compared to 3 Tesla. However, the interpulse time for the spectral-spatial composite RF pulses used in spectroscopic SSFP sequences at 3 Tesla becomes also shorter with increasing field strength causing gradient switching problems with commercial gradient systems. Therefore, these spectral-spatial RF pulses used for both spatial selection and chemical shift selective suppression of water and lipid resonances at 3 Tesla have to be replaced at 7 Tesla. In this work, first *in vivo* results of a modification of „spectroscopic Missing Pulse - SSFP" [2] for 3D ^{1}H MRSI of the human brain at 7 Tesla are presented in which the spectral-spatial RF pulses are substituted by only spatially selective RF pulses, while water and lipids are suppressed by two spectrally selective Gaussian RF pulses. Since the same sequence timing as for 3 Tesla was used, this first study aimed primarily at an increased spectral resolution, while the sequence has not been optimized yet with respect to maximum SNR_t.

Materials and methods

The modified spMP-SSFP sequence for 7 Tesla is shown in Fig.1. RF excitation is implemented with slice selective Hamming filtered sinc-pulses of 2ms duration. The second RF pulse excites an orthogonal slice with respect to the slice of the first RF pulse enabling 2D spatial preselection because only spins from the intersection of both slices are refocused at the echo time (TE). A 180° phase shift for the second excitation RF pulse is used for maximum signal intensity of signals with uncoupled spins. Two spectrally selective 7.5ms Gaussian 180° RF pulses incorporated in the first T interval with subsequent spoiler gradients serve for water as well as for fat signal suppression (ws/fs). Measurement parameters for the 3D spMP-SSFP sequence were as follows: FOV (x,y,z): 190x190x105 mm³, VOI (x,y,z): 190x115x45 mm³, phase encoding steps (x,y,z): 24x24x12, TE=122ms, TR=183ms, α_1=40°, α_2=-40°, acquisition bandwidth=5000Hz, 512 spectral data points, acquisition weighted k-space sampling with 2 averages, total measurement time: 8min53s including 64 dummy scans. The nominal voxel size of 0.55 cm³ was increased to 1.95 cm³ by the acquisition weighting. An eight-channel head array coil (RAPID Biomedical, Rimpar, Germany) was used for transmitting and receiving at a 7 Tesla whole body scanner (Siemens Medical Solutions, Erlangen, Germany). Post-processing consisted of apodization in k_ω with a sine-bell function, in k_x and k_y with a Hamming function (α_H=0.66) (no apodization in k_z), zerofilling from 512 to 4096 spectral data points and Fourier transformation. Spectra from single array elements were then combined offline using the water signal of a reference water scan for weighting and normalizing [3]. The combined spectra are displayed in magnitude mode without decreasing the spectral resolution due to the acquisition of full spin echoes with spMP-SSFP. Reference images were acquired with a T_1-weighted MP-RAGE sequence.

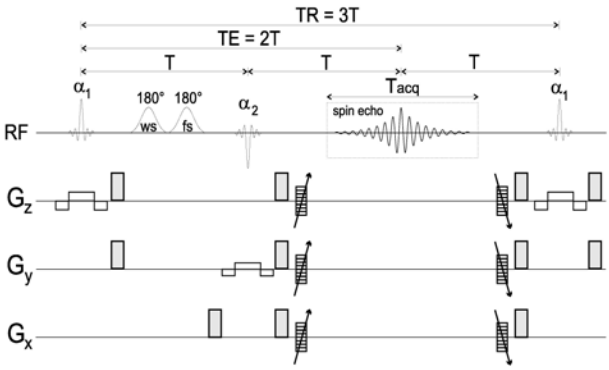

Fig.1: Spectroscopic Missing Pulse - SSFP sequence for 7 Tesla

Results

Fig.2 shows magnitude spectra from 1.0 to 4.3 ppm of one slice of the 3D ^{1}H MRSI measurement. Positioning of the FOV and the VOI is marked in the corresponding reference image. The displayed part of the spectra is also marked. The spatial selection works very well as can be seen by noisy spectra of voxels outside the VOI in frontal and occipital regions. A 5x5 spectra matrix of another slice is shown in Fig.3 to demonstrate the spectral quality. In some voxels lipid contamination from voxels located near the scalp are visible indicating that lipid suppression was not perfect.

Discussion and conclusions

This first study using SSFP sequences for fast 3D ^{1}H MRSI of the human brain *in vivo* at 7 Tesla shows the feasibility of using spMP-SSFP without spectral-spatial RF pulses used for 3D ^{1}H MRSI at 3 Tesla. Water and lipid suppression by additional Gaussian RF pulses works quite well but could be improved by adiabatic 180° pulses especially for lipid suppression. However, this will lead to problems with RF power deposition since SAR values of the spMP-SSFP sequence were already 99% of the allowed value. Currently an alternative approach for lipid suppression is under investigation using low SAR slice selective outer volume suppression pulses. With the same sequence timing used for 3 Tesla, an increased spectral resolution is achieved compared to 3 Tesla. The flip angles of 40° of the RF excitation pulses were not optimal in terms of SNR_t which would have been maximal for flip angles of 50°. However, considering the SAR limits, maximum SNR_t was sacrificed for a better water and lipid suppression with 180° Gaussian RF pulses. In conclusion, fast 3D ^{1}H MRSI of the human brain *in vivo* at 7 Tesla using spMP-SSFP is feasible, but future work has to be done to further increase the SNR_t and the spectral quality, in spite of the constraints given by the SAR limit and problems arising from B_1 inhomogeneities.

References

[1] Geppert C et al, Proc ESMRMB 2005, no.224. [2] Schuster C et al, Proc ISMRM 2006, no.71 and Magn Res Med (*in press*). [3] Roemer PB et al, Magn Res Med 1990;16:192-225

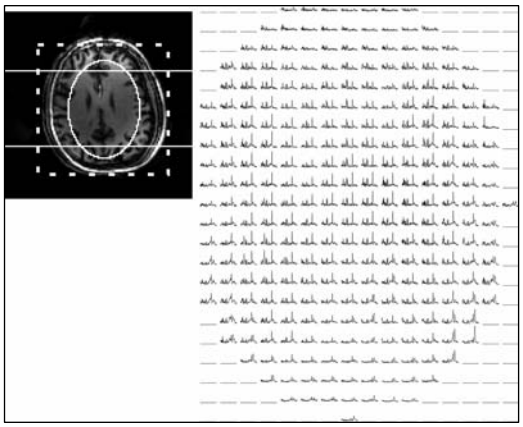

Fig.2: Magnitude spectra (1.0-4.3ppm) of a representative slice of the 3D ^{1}H MRSI measurement. In reference image: FOV: dashed line, VOI: solid lines, displayed region: ellipsoid.

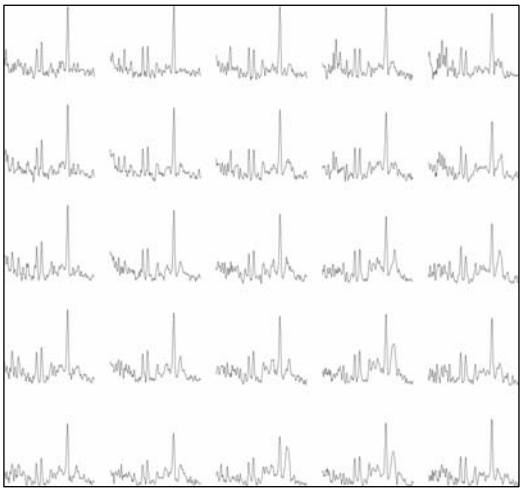

Fig.3: 5x5 magnitude spectra (1.0-4.3ppm) from a second slice showing lipid contamination in some voxels.