High-resolution free induction decay proton MRSI in the human brain at 9.4 T

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Purpose:

Proton MRSI based on free induction decay acquisition (FID MRSI) is a promising technique to be used for spectroscopic imaging at ultra-high magnetic field [1, 2]. This technique minimizes signal losses due to T_2 relaxation and avoids in-plane chemical shift displacement. Lipid contaminations arising from the subcutaneous fatty tissue can be reduced with additional outer volume suppression [1], or by optimization of the point spread function (high spatial resolution and Hamming filter) [2]. However, due to a small acquisition delay, which is caused by the residual RF pulse duration between its reference point and the end of the pulse as well as rephasing and phase encoding gradients, the first points of the acquired FID signal are missing. This leads to the rise of first-order phase problems which may hamper further quantitative analysis. Our aim was to examine the feasibility of high-resolution FID MRSI of the healthy human brain at the field strength of 9.4 T. In the presented approach the missing points of the FID signal were reconstructed with an autoregressive model so that the phase problems present in the acquired spectra could be minimized.

Methods:

In-vivo measurements were carried out using a 9.4 T whole body scanner (Siemens, Erlangen, Germany). Spectra from two healthy volunteers were acquired using an in-house developed 16 channel transmit/ 31 channel receive coil [3]. For maximizing the efficiency over the FoV the coil operated in circular-polarized mode. Second order image based B_0 shimming was performed. Water suppressed MRSI data were collected from the superior part of the brain with a customized FID MRSI sequence with the following parameters: TR 340 ms, acquisition delay (TE) 2.3 ms, resolution: 64×64 voxels, acquisition duration: 128 ms, spectral bandwidth: 4000 Hz, 1024 complex data points, FoV: 200×200 mm^2, nominal voxel size: 3.1×3.1×10 mm^3. A hermite RF-pulse was used for excitation and the flip angle was adjusted to the Ernst angle (35°) calculated for NAA using known T_1 value at 9.4 T [4]. Through-plane chemical shift displacement was reduced to 1 mm per ppm by increasing the bandwidth of the excitation pulse to 4300 Hz. A weighted phase encoding scheme applied during data acquisition and spatial Hamming filtering allowed for improving the shape of the point spread function. This minimized lipid contaminations in the measured spectra, as the acquisition was done without any additional fat saturation. Optimal combination of signals from the receive channels was calculated with the adaptive combine method [5]. The missing points at the beginning of each acquired FID signal were reconstructed using an autoregressive model based on the Burg method [6]. Subsequently, spectra were zerofilled to 2k points and Hanning filtered (time constant of 100 ms). Finally the baseline was fitted using spline interpolation with knots selected at those points of the spectrum, where no metabolite signals were expected and subtracted. Spectral post-processing was done with custom software written in Matlab (The MathWorks, Natick, MA, USA).

Results:

Figs. 1 and 2 shows spectra acquired from the brain of both volunteers. The applied reconstruction of the missing FID points allowed significant reduction of the phase distortions typical for the spectra acquired with FID MRSI, so that overall the spectra present a good quality. Acquisition at high in-plane resolution combined with k-space acquisition weighting and Hamming filtering minimized contaminations with lipid signals. Even in voxels closely located to the skull (Fig.2) lipid contamination does not negatively affect the spectral range of interest between 2 and 4 ppm.

Discussion/Conclusion:

We demonstrated that FID MRSI of the human brain at the field strength of 9.4 T is feasible. It was also possible to reconstruct the missing FID points, so that the phase distortions present in the spectra could be minimized. Additional improvements might be achieved with B_1 field shimming, which, due to regulatory issues, was not done in the present study. Moreover, a further decrease of the acquisition delay possible by using RF coils with higher transmit efficiency or self-refocusing RF pulses would reduce the number of missing FID points, thus minimizing phase distortions. In conclusion, the initial experience with FID MRSI in the human brain at the field strength of 9.4T shows that this technique is highly promising since it addresses the most critical problems of chemical shift displacement and signal losses due to fast T_2 relaxation of metabolites that are even more severe than at 7T.

References:

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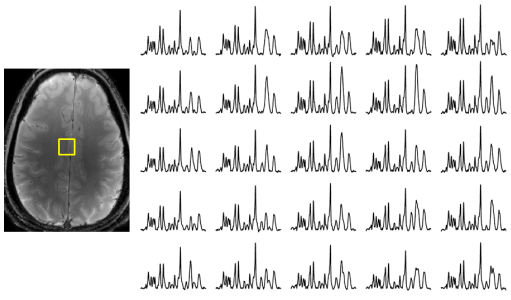

Fig. 1: Gradient echo scout and a 5 × 5 voxels spectra matrix acquired from the brain of the first volunteer (male, 26 years old).

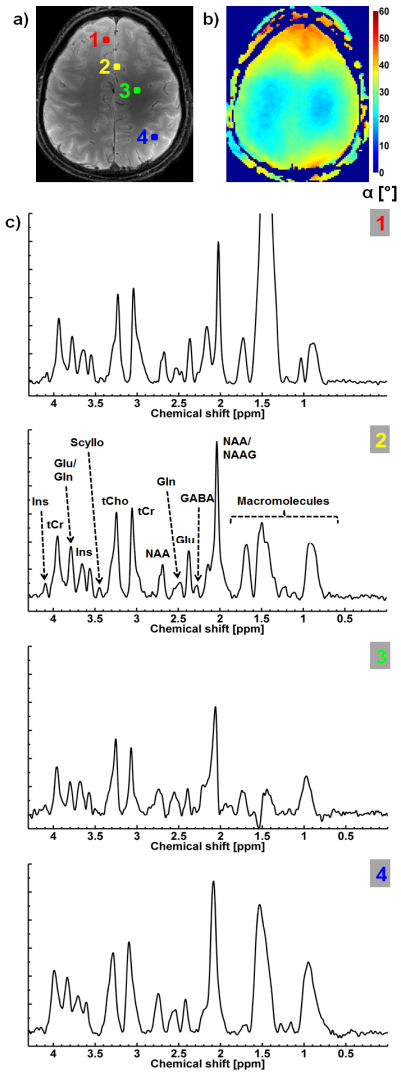

Fig. 2: Gradient-echo scout (a), flip angle map acquired with AFI sequence at the reference voltage of 300V and with targeted flip angle of 60° (b) and an example of spectra (c) acquired from the brain of the second volunteer (male, 33 years old). Spectra presented on the right are originating from the locations marked with numbers 1 to 4. MRSI data were acquired within 21 min.