SSFP based fast ^{1}H spectroscopic imaging on the human brain at 3T using k-space weighted acquisition

C. Geppert[1], W. Dreher[1], M. Althaus[1], C. Schuster[1], D. Leibfritz[1]
[1]FB2(Chemie), Universität Bremen, Bremen, Bremen, Germany

Introduction:

As the minimum total measurement time (T_{min}) and the signal-to-noise ratio per unit measurement time (SNR_t) are crucial demands for the development in ^{1}H spectroscopic imaging (SI), various fast SI methods have been proposed. In recent works, the use of the steady state free precession (SSFP) condition, well established in MRI, was suggested for fast ^{31}P [1] and ^{1}H SI [2]. SSFP based methods denote both a high SNR_t and a short T_{min} thus making fast 3D ^{1}H SI possible. However, because of the short acquisition times per repetition time, the required spectroscopic resolution suggests its preferred use at higher B_0. While this has been shown in vivo in measurements on the rat brain at 4.7 T [2], this paper presents the application of the spectroscopic CE-FAST sequence on the human brain at 3T allowing 3D ^{1}H SI within less than 4 minutes. Using k-space weighted acquisition [3, 4], the SNR_t was further increased and the spatial point spread function (PSF) was optimized.

Methods:

The scheme of the applied pulse sequence is displayed in Fig. 1. Excitation/refocusing of metabolite signals is done by a chemical shift selective hard pulse train [5]. This composite pulse (40° flip angle, 1–τ–1–τ–8–τ–8–τ–1–τ–1, excitation minima at multiples of 1/τ) suppresses resonances from water and lipids simultaneously. Subsequently crusher gradients select only the echo-like signal S2 corresponding to the imaging sequence CE-FAST [6]. Thus off-resonance effects are overcome which occur if also the FID-like signal S1 was acquired. However, all phase encoding gradients are balanced after the acquisition window. A k-space weighted acquisition scheme was implemented using a spherical reduction of the sampled k-space as well as Hamming weighted number of averages [3, 4]. Fig. 2 represents the k-space accumulation scheme for a plane through the center of k-space, derived from a 16x16 matrix. This k-space weighted averaging scheme is applied to phase encoding in all three dimensions, to reduce T_{min}, to increase the SNR_t, and to optimize the spatial PSF. By this means also problems with insufficient water suppression (due to local B_0 inhomogeneities) or strong lipid contamination are reduced.

The sequence was implemented on a Siemens Allegra 3T head scanner using a standard birdcage head coil. Subsequent to automatic global shimming spatially selective manual shimming was performed. The FOV was 220^3 mm^3. 64 dummy cycles were performed to establish the steady state. The acquisition window was 64 ms. A TR of 83 ms resulted in a total measurement time for the weighted 3D data set of 3:32 min as compared to 5:50 for a rectangular unweighted 16*16*16 matrix, corresponding to 2479 and 4096 acquisitions, respectively. Post processing included cosine apodization in the time domain, zero filling to 1K*16*16*16, FFT and phase correction using IDL software. In vivo experiments were performed on healthy volunteers.

Results and Discussion:

Fig. 3 shows a matrix of 9x7 spectra with a spectral range from 4.4-0 ppm overlaying a T1-weighted image of the respective slice. The reduction of metabolite signals in voxels from the ventricles can clearly be seen. Metabolite maps of the predominant singlet signals of N-acetyl aspartate (NAA), total creatine (tCr) and choline containing compounds (Cho) are shown in Fig.4. Voxels partially incorporating the surrounding tissue show a predominant fat signal but these signals are sufficiently localized without significant signal 'bleeding'. Currently, it was not possible to calculate reliable metabolic images for other metabolites such as myo-inositol (Ins), probably due to the rather long effective echo time used.

Both k-space reduction and weighting cause a slight broadening of the main lobe of the spatial response function but the contamination of voxels with signals from surrounding lipids and water from areas with large B_0 inhomogeneities is substantially reduced. Therefore a larger total number of voxels can be evaluated as compared to conventional rectangular unweighted acquisition.

Conclusion:

Despite the lower B_0 as compared to [2], spectroscopic CE-FAST was successfully performed on healthy volunteers at 3T. SSFP based SI seems promising for applications where minimum measurement time is the key issue. Since the lack of spatial selectivity is a drawback of the current implementation of spectroscopic CE-FAST, spectral-spatial RF pulses are currently tested. Further improvements may be expected from the detection of the FID-like signal S1 which, however, will require improved water and lipid suppression.

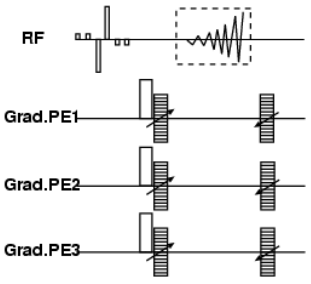

Fig.1

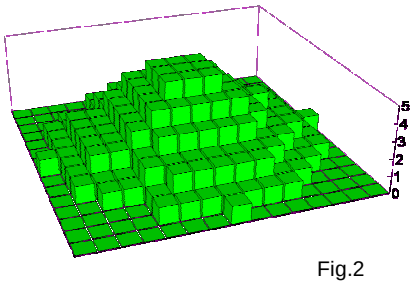

Fig.2

Fig. 1: Scheme of the spectroscopic CE-FAST sequence
Fig. 2: k-space sample scheme (weighting given by numbers)
Fig. 3: Matrix of brain spectra from one slice with underlaid image of the corresponding slice
Fig. 4: Metabolite maps of NAA, tCr, Cho (top to bottom, interpolated from 10x11 spectra matrix)

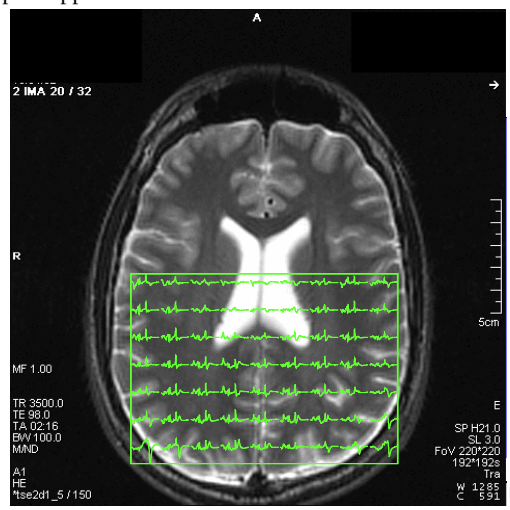

Fig. 3

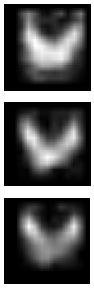

Fig. 4

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