31P imaging of the human brain with balanced SSFP - preliminary results

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Introduction: Magnetic Resonance Spectroscopy (MRS) of 31P is a promising tool for the examination of several pathologies and metabolic processes. E.g., particular interest lies in the cortical energy metabolism of migraine patients, where 31P spectroscopy is applied with the aim of quantifying metabolite ratios [1,2]. A beneficial reduction of total scan time could result from utilisation of fast pulse sequences, which can acquire spatial and spectroscopic information at the same time. We show preliminary results of imaging 31P in the brain with a balanced SSFP (bSSFP) sequence [3], as this sequence has potential to be the basic signal generating sequence in several fast spatial-spectroscopic methods [3,4] due to its high steady state signal. However, the concentration of Phosphocreatine (PCr) in brain tissue is approximately eight times lower in muscle (~3 mM vs. ~26 mM [5]), which puts a further challenge on 31P brain studies.

Method: Experiments were performed on a 3T Siemens Trio Scanner, equipped with a quadrature 1H/31P head coil (Rapid, Rimpar, Germany). After performing careful adjustments and shimming, a standard 2D bSSFP sequence was utilized in order to acquire images from 31P in a phantom and in volunteers. The phantom consisted of a cylinder with diameter of 5 cm and height of 3 cm, filled with a 100mM solution of phenylphosphonic acid (PPA), with T1~6.7s and T2~0.65s. The phantom image data were acquired with the following parameters: FOV 90mm*90mm, matrix size 16*16, in plane resolution 5.6 mm * 5.6 mm, slice thickness 40 mm, flip angle = 47°, TR = 6.59 ms, TE = 3.3 ms, BW 800Hz/Px, 400 averages, total acquisition time 42.2 s. Parameters for the 2D acquisition in transversal view on a volunteer head were: FOV 560 mm* 280 mm, matrix size 16*8, in plane resolution 35 mm * 35 mm, slice thickness 80 mm, flip angle = 30°, TR = 5.84 ms, TE = 2.92 ms, BW 500 Hz/Px, 2000 averages, total acquisition time 93.5 s. An other experiment was a transversal 2D projection over the whole head with FOV 560 mm* 280 mm, matrix size 32*16, in plane resolution 18 mm * 18 mm, slice thickness 500 mm, flip angle = 28°, TR = 5.04 ms, TE = 2.52 ms, BW 500 Hz/Px, 2000 (4000) averages, total acquisition time 162 s (323 s).
Additionally, a 31P spectrum of the whole head with a spin echo sequence was acquired with TR = 10 s, TE = 4 ms, acquisition bandwidth 4000 Hz, 16 averages, excitation bandwidth 1kHz. SNR in the images is estimated with the formula

$$\mathrm{SNR} \propto \text{voxel volume} \cdot \text{concentration} \cdot \sqrt{\text{No. of phase encodings} \cdot \text{averages/bandwith per pixel}} \quad (1)$$

Results: The spectrum acquired from the whole head is shown in Fig. 1. Note that β-ATP was largely suppressed as the narrow excitation bandwidth was deliberately chosen because a series of such spectra is intended to be used for T2 quantification. The phantom balanced SSFP image is shown in Fig. 2. Note that the concentration of PPA in the phantom is of about 30 time higher than the concentration of PCr in the brain (~3mM, see [5]). The in vivo head images are depicted in Fig. 3 and Fig. 4. In Fig. 4, the images are projections over the whole head, which means there is also contribution from PCr in muscles (concentration ~26 mM [5]). The SNR in the images from Fig. 2-4 is difficult to quantify, however, Eq. 1 predicts a SNR ratio of the phantom image and head image from Fig. 3 of 0.21, when identical steady state values for the voxel signal underlying a balanced SSFP sequence are assumed. However, this ratio is hardly visible in the presented images. The SNR gain of about sqrt(2) is visible Fig. 4, where 4b shows the image acquired with twice the number of averages than were used in 4a.

Discussion: The preliminary image data show that there is need of examination of the mechanisms that influence the steady state signal that can be obtained from 31P metabolites in the human brain with bSSFP. In comparison with data acquired from a PPA phantom, the in vivo SNR is lower than estimated. A potential effect that can lead to a decrease in the SSFP signal is magnetization transfer [6] that becomes relevant through creatine kinase activity according to the reaction PCr + ADP ↔ Cr + ATP [7]. When more thorough understanding of the bSSFP signal from 31P metabolites is accumulated, balanced SSFP sequence can be a valuable tool for rapidly acquiring spatial-spectral information from 31P in the brain, in analogy to [3], where balanced SSFP was evaluated to be a promising method for 31PMRS of the calf muscle.

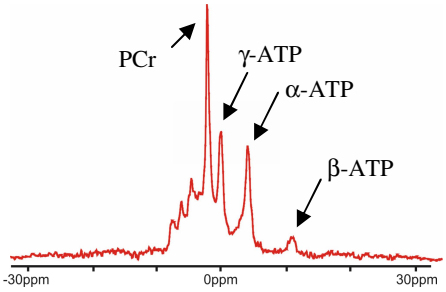

Fig.1: 31P spectrum of a volunteer brain, acquired with a spin echo sequence.

Fig. 2: 31P 2D bSSFP image of a PPA phantom.

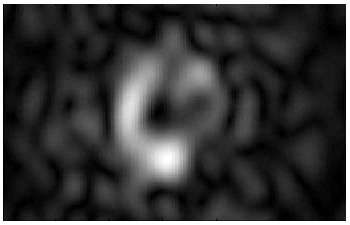

Fig. 3: 31P 2D bSSFP image of a volunteer brain, slice thickness 80mm, 2000 averages.

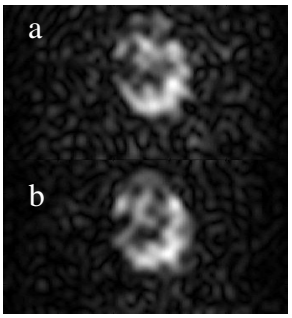

Fig. 4: 31P 2D bSSFP images of the same brain as in Fig.3, slice thickness 500mm. a) 2000 averages, b) 4000 averages

References: [1]Montagna et al., Neurology 1994,44(4);666-9 [2]Schulz et al., Brain 2007, Oct.22 [3]Speck et al., MRM 2002,48;633-639 [4]Leupold et al., Magma 2006,19(5);267-273 [5] Hetherington et al., MRM 2001,45;46-52 [6] Bieri and Scheffler, MRM 2006,56;1067-1074 [7]Mora et al., MRM 1992,26;100-115