Functional MRI in the rat brain with single-shot gradient echo EPI at 16.4 T

D. Z. Balla[1], H. M. Wiesner[1], G. Shajan[1], and R. Pohmann[1]
[1]High-Field MR Center, Max-Planck-Institute for Biological Cybernetics, Tuebingen, Germany

Introduction

Gradient echo (GE) EPI is a standard sequence used in fMRI studies at clinical field strengths. Yet, the enhanced sensitivity of high field research spectrometers to field inhomogeneities and gradient nonlinearities hinder the implementation of high-quality imaging with GE-EPI, especially single-shot EPI. There are only a handful of publications using GE-EPI in small animals above 9.4 Tesla. However, the high SNR and spatial specificity expected at ultra-high field fMRI calls for a thorough investigation of the BOLD signal characteristics at such field strengths. Therefore, the aim of this work was to adapt single-shot GE-EPI for fMRI at 16.4 T and to develop an experimental protocol as basis for future fMRI-investigations.

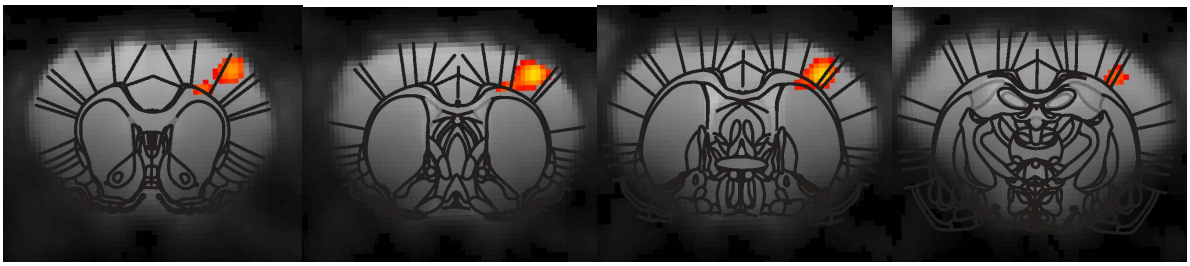
Methods

Experiments were performed on a horizontal bore 16.4 T Magnex magnet interfaced to a Bruker Biospec research spectrometer. The gradient system from Resonance Research with an inner diameter of 12 cm is capable of switching 1 T/m gradients within 212 µs. For transmission and reception a 22 mm loop coil, connected to a homebuilt preamplifier, was employed. Healthy adult rats were used for in vivo parameter optimization and fMRI studies with extensive monitoring of the physiological status. The protocol for longitudinal fMRI on rats was adapted from Weber et al. [1] with a few modifications: 1. catheters were implanted under isoflurane anesthesia into the tail artery and vein for blood sampling and Medetomidine infusion, respectively; 2. the Medetomidine infusion rate had to be increased to 0.14 mg/kg/h to maintain stable anesthesia; 3. the animals breathed freely through a mask a mixture of O_2 and room-air (1:4 v/v); 4. exhaled gas was drawn from the mask and analyzed for changes in pCO_2 or pO_2. Electrical forepaw stimulation was performed using 300 µs pulses with a strength of 2.0 mA applied at a rate of 3 Hz through subcutaneously inserted electrodes. In a 6 minutes acquisition 5 equally spaced stimulation blocks were applied. Local shimming was performed with FASTMAP. The EPI method included in the Paravision 5.0 (Bruker) method library was used with sine-shaped gradients and an echo-position at 25 %. The sampling matrix of 128 x 64 x 9 covered a 3.2 x 1.6 x 0.9 cm^3 FOV, resulting in an isotropic in-plane resolution of 250 µm with a slice thickness of 1 mm. The echo time could be reduced to 7 ms. Signal contribution from outside the brain was suppressed by four saturation slices. A full volume was acquired every 3 seconds. Uncorrected activation maps with a significance threshold of p=0.01 were generated with the FEAT-utility of the FSL-software [2], implying motion correction and spatial smoothing before fitting. The model function contained the Gaussian weighted stimulation block-design, its temporal derivative and the motion parameters.

Results

GE-EPI images with activation map overlays for a representative dataset are presented in Fig.1. Motion correction and including the motion parameters in the model were essential to detect specific activation in the primary sensory cortex for the forelimb [3]. A tentative assignment of the activated regions to the anatomy is presented in Fig. 2 for the slices 2 to 5 (from left to right). Additional regions with significant signal changes are outside the brain and probably due to incompletely corrected motion effects. The resulting activation maps have high quality and are suitable for characterization of the BOLD signal at 16.4 T.

Figure 2: Tentative assignment of the activation maps to the rat brain anatomy [3].



Conclusion

We reported here the first stimulation-induced fMRI study with EPI in rats at 16.4T. GE-EPI provided high quality images after a relatively short parameter optimization period. The technique was suitable for the acquisition of fMRI timeseries although effects of motion had to be corrected in a post-processing step.

References

[1] Weber et al., NeuroImage 29:1303 (2006); [2] Smith et al., Neuroimage 22:208 (2004); [3] Paxinos and Watson, The Rat Brain (2007)

Figure 1