Functional Magnetic Resonance Imaging Using PROPELLER EPI

M. Krämer[1], T. H. Jochimsen[1], M. Roth[1], and J. R. Reichenbach[1]
[1]Medical Physics Group, Department of Diagnostic and Interventional Radiology, Jena University Hospital, Jena, Germany

Introduction

Functional Magnetic Resonance Imaging (fMRI) is usually based on a standard 64x64 single shot EPI sequence. However, this sequence delivers images with poor spatial resolution. Increasing the resolution, e.g. by multi-shot acquisition, generally leads to unacceptable long scan times. With the PROPELLER [1] sequence and its combination with an EPI signal readout it has been shown that reasonable results can be achieved [2] if a sophisticated image reconstruction is applied. In our work, we investigate the possibility of using PROPELLER-EPI for improving spatial and temporal resolution in fMRI experiments.

Methods

PROPELLER-EPI is a sequence where only a small blade around the k-space center is measured after each RF excitation. This blade is then rotated around the k-space center until the entire k-space has been covered. The readout of a complete blade is achieved by a single EPI trajectory. We oriented our blades along the readout direction, or long axis (LAP-EPI), meaning that the blades are narrower in the phase encoding direction. The advantage for fMRI is that each blade, independent of its rotation, will capture the same area in the center of k-space. This is important since one can assume that the activations in fMRI are located in the k-space center. When applying this technique to fMRI it is, therefore, not necessary to cover the entire k-space with each repetition, rather is it enough to measure only a single blade and then later combine the rotated blades from subsequent repetitions using a sliding window approach. As a proof of concept, our experiments were aimed to verify that a sliding window reconstruction of a high resolution LAP-EPI sequence will produce feasible results for fMRI analysis.

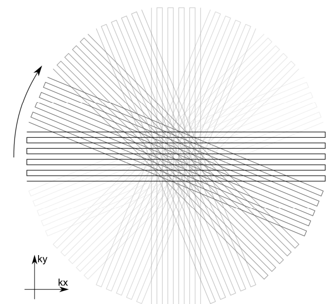

Fig. 1. LAP-EPI trajectory

Two subjects were scanned, and besides a high resolution 256x256 MPRAGE scan, which was used for later data alignment, each subject had to undergo four fMRI experiments. As fMRI stimulations, right handed finger tapping and visual stimulation with a black and white checkerboard were used. Each fMRI trial was performed twice resulting in a scan order of 1) 128x128 LAP-EPI visual, 2) 128x128 LAP-EPI finger tapping, 3) 64x64 EPI visual, 4) 64x64 EPI finger tapping and 5) MPRAGE for each subject. The length of each fMRI trial was 320s with 40s rest and activation periods for finger tapping and 30s activation and 24s resting periods for visual stimulation.

The scans were performed on a Siemens 3T Magnetom Trio with the following parameters: 192x192mm field of view, 20 slices, 3.0mm slice thickness, 1.5mm gap between slices, 100kHz acquisition bandwidth, 2000ms repetition-time, 21.8ms echo time and a PROPELLER sequence using 8 blades. For the LAP-EPI scans 20 full k-space images were collected, resulting in 152 repetitions with a nominal repetition time of 2000ms after the sliding window reconstruction. Image reconstruction and PROPELLER sequence design were carried out using ODIN [5] (Object-oriented Development Interface for NMR). Statistical analysis was performed both using FEAT (FMRI Expert Analysis Tool) and a simple correlation analysis in MiView (Viewer for medical image files from the ODIN package). For better comparison, the calculated activation clusters were mapped onto the high resolution MPRAGE scan.

Results

Figures 2 and 3 demonstrate that the high resolution 128x128 LAP-EPI scan yields activation maps which are detailed enough to show that the activations are located along the cortex in gray matter regions. When comparing the activations to the standard 64x64 EPI scan, one can also see a very good correlation between the shape and location of the activation clusters, where the LAP-EPI maps show more details due to the higher resolution made possible by the PROPELLER sequence. It appears that in the standard EPI scans, the clusters showing the maximum activations are shifted into white matter regions whereas LAP-EPI localizes the activations well within the cortex. Additionally, Figure 3 shows that the visual EPI activations are shifted downwards, meaning that LAP-EPI is significantly less prone to the typical geometrical distortions of single-shot EPI measurements.

a)
b)

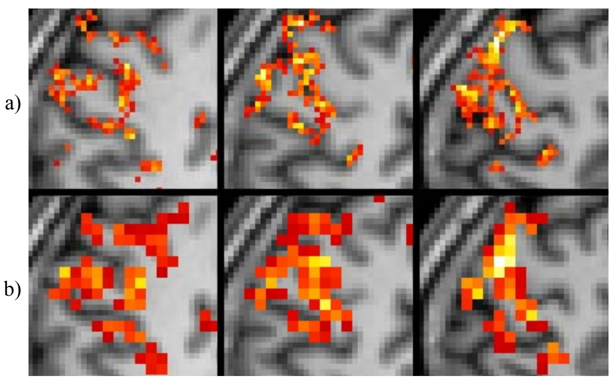

Fig. 2. Activations maps for finger tapping of slices 12, 13 and 14. a) 128x128 LAP-EPI , b) 64x64 EPI (mapped on MPRAGE scan)

Discussion

Our initial experiments demonstrate that LAP-EPI combined with a sliding window reconstruction is suitable for simple fMRI experiments. With the PROPELLER technique, higher spatial resolutions are possible without the need for an increased scan time. This gives more freedom when choosing the measurement parameters for fMRI experiments since an increase in temporal resolution should also be possible. Using PROPELLER sequences in fMRI has the advantages that it is a self-navigated sequence, where the k-space center is acquired in each shot, and that it offers a higher SNR than regular EPI. Two further improvements of the PROPELLER technique, particularly interesting for fMRI, could be to combine the sliding window with a keyhole reconstruction, and to combine the EPI acquisition with parallel imaging to obtain even higher spatial resolutions.

a)
b)

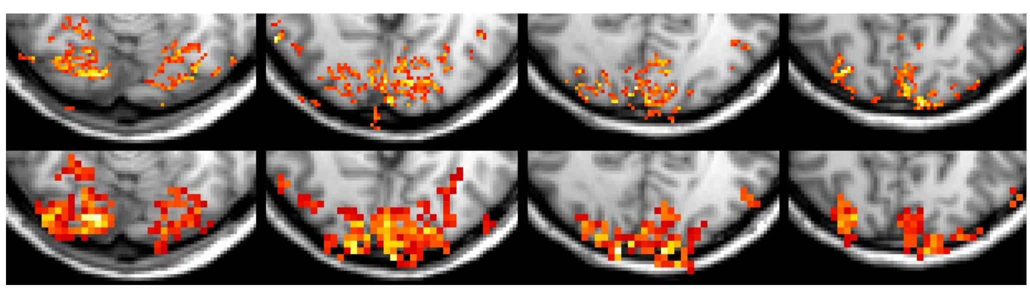

Fig. 3. Activations for visual stimulation of slices 2,4,6 and 8. a) 128x128 LAP-EPI, b) 64x64 EPI (mapped on MPRAGE)

References

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