Investigating the function of the cardiovascular and respiratory centers in the brain stem by breath-holding using reduced FOV EPI technique

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Introduction

In skull base, the susceptibility of regional magnetic field inhomogeneity usually severely distorts the EPI images due to long readout train. One of the remedies is to shorten the acquisition window. In this work, reduced field-of-view (rFOV) along the phase encoding direction is proposed to reduce the phase error aggregation. In this study, we use zoom EPI technique [1] to avoid the aliasing artifacts from signal outside the rFOV. Due to the small number of phase encoding, the distortions are greatly reduced without the need of acceleration by parallel techniques. In the past, functional MRI studies in the brain stem are limited by the imaging distortion on EPI-based pulse sequence. Although it could be remedied by line-scan technique [2], temporal resolution is unavoidably sacrificed. The purpose of this study is to use the zoom-EPI technique to acquire distortion-free EPI images and, by which, to approach the function of the cardiovascular and respiratory center by using breath-hold method.

Material and method

Image Acquisition: A multi-slice pre-IR inner volume excitation spin echo EPI sequence as shown in Fig was introduced in the experiment. A non-selective inversion hard pulse was utilized followed by the excitation. A 7-lobe selective echo pulse for optimal slice selection profile was applied along the phase encoding direction. And EPI acquisition was adopted for sampling the image data. In addition, two crusher gradients clipping the selective echo pulse was performed to minimize the signal from the imperfect refocus pulse and from outside of the FOV. Consequently, the contribution to the echo signal would solely come out from the intersection where is irradiated by the excitation and the refocusing pulses. As for the multi-slice scheme, each excitation is equally separated in time within one repetition duration (TR).

Functional Imaging Experiment: Volunteer experiment was performed on a 3.0 T Philips Achieva system to image the functional response of breath holding around the midbrain. The acquisition matrix was 96x20 with slice thickness set to 5 mm leading to the resolution of 2.29x2.29x5 mm^3. The echo time was 95 ms with TR set to 3000ms. 50 sequential volume acquisitions were performed following 20 dummy scans to stabilize the signal. During the periods from the 11^{th} scan to 20^{th} scan and from the 31^{st} to 40^{th} scan, the volunteer was asked to hold the breath and return to free breathing for the rest scans.

Data Analysis: The acquired images were firstly smoothed by a Gaussian kernel with FWHM 5mm. Subsequently, voxel based analysis was performed on SPM2 using general linear model. The model regressor was generated by the hemodynamic response convolved to a block-wise square function, as the designed parameter in the volunteer experiment. The voxels having statistical significance at the level of $p<0.005$ with contiguous cluster size over 10 voxels were regarded as the activation site.

Results

Fig 1. demonstrates the less distorted EPI images of the brain stem on saggital planes, and, shows activated signals in the lower pons.
The active pixels are displayed by hot color bar. The average of T2* signal in ROI is displayed in Fig 2. The BOLD signal change is about 5% during breasthold on and off.

Discussion

Our results demonstrate undistorted spin-echo EPI images of the brain stem using the rFOV technique. The function of the cardiovascular and respiratory centers in the brain stem could therefore be evaluated on EPI-based fMRI. By the breath-hold method, which causes accumulation of arterial tension of CO2, activations of the cardiovascular and respiratory centers at the lower pons are successfully demonstrated.

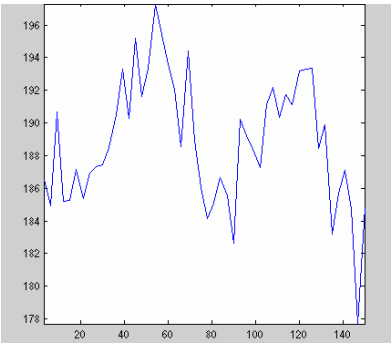

Fig. 2. Signal-time curves in the functional task of 2 cycles of breath holding.

References

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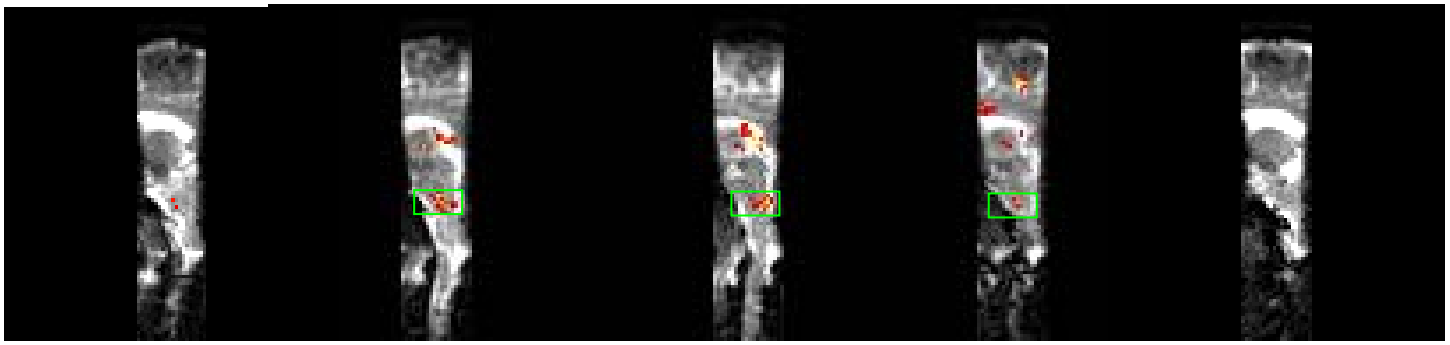

Fig1. Sagittal EPI images covering brainstem.