Minimizing the Effect of Body Motion on EPI Time Series by Digital Tuning

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Introduction There are growing interests in fMRI study of alert, behaving monkeys. One of the technical challenges is from body motion of the monkey subjects. Although head motion in the field-of-view (FOV) can be well restrained by using a headpost, body motion is typically less restricted. Motion outside FOV still causes changes of magnetic field inside FOV and results in varying geometrical distortion in the EPI time series [1]. Training the monkey to keep still during a brief period of time [2], and throwing away images corrupted by motion are often needed in monkey fMRI. We propose a simple post processing procedure to restore the distorted images by digital tuning during EPI reconstruction.

Modeling Body motion redistributes the mass of bulk susceptibility in the magnet and changes the shim inside the FOV. Our hypothesis is that the change of the static field can be approximated by constant and linear terms within the FOV of a thin-slice image. Specifically, the field change is described by Δf (global frequency), ΔGx (read gradient), and ΔGy (phase gradient). The gradient changes can be taken into account by an altered k-space trajectory, as shown in Fig. 1, during EPI

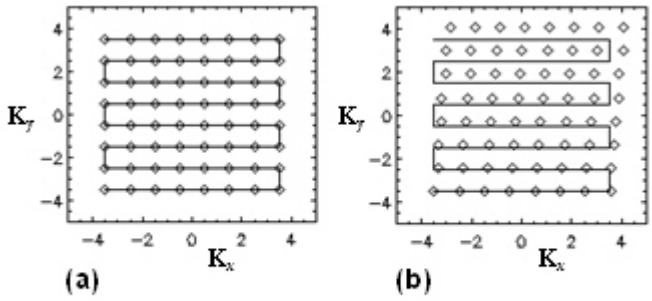

Fig. 1 K-space trajectory of single-shot EPI with 8x8 matrix. An ideal trajectory (a) is altered by presence of ΔGx and ΔGy.

Methods Single-shot EPI data from an axial plane were acquired with a standard gradient-echo EPI sequence on a 4.7T Bruker scanner. FOV = 128x96 mm^2, matrix size = 128x96, sweeping bandwidth = 200KHz. Changes in shim setting were manually introduced in between EPI acquisitions on a phantom to simulate "body motion". Existing EPI time series from a functional study of alert monkey were used to test the proposed procedure.

In image reconstruction of a time series, one frame was chosen as a reference while other frames were subject to a 4-parameter tuning procedure. The first 3 parameters, Δf, ΔGx, and ΔGy, could cause geometrical shift or distortion. The 4th parameter was a scaling factor for intensity applied to the entire image. The goal was to minimize the total energy in the difference image between the reference frame and current frame.

A linear phase correction along the EPI echo train canceled Δf; a linear phase correction along x after a 1D-FT in Kx restored sampling shift in Kx (due to ΔGx); a fast regridding method [3] corrected shift in Ky (due to ΔGy); the deviation in step length along Kx between even and odd echoes was deemed to be small enough to ignore. The scaling factor multiplied on the magnitude image minimizes global intensity variation.

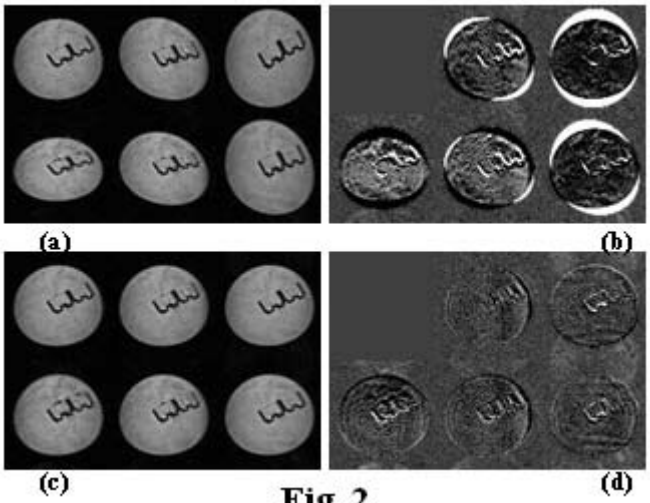

Fig. 2

Results and Discussion When linear x and y shims are manually changed, it results in severe image distortion as shown in Fig 2(a). The differences relative to the reference frame are shown in Fig 2 (b). After digital tuning, distortion is corrected as in Fig 2(c) and difference images contain much less energy as shown in Fig. 2(d).

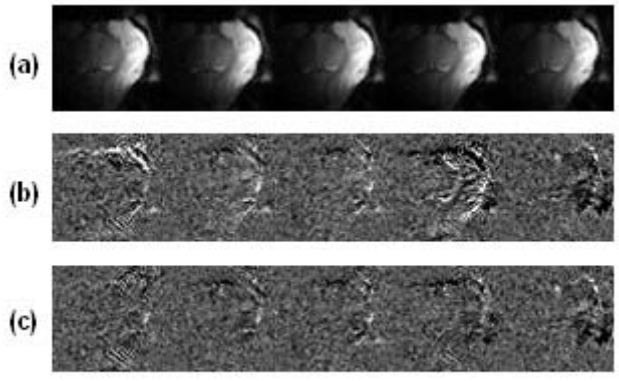

Fig. 3

Fig. 3(a) shows consecutive time frames from real fMRI scans on an alert monkey. They may be affected by body motion and show elevated differences relative to a reference frame, as shown in Fig. 3(b). After digital tuning, inter-frame differences are reduced significantly, as demonstrated in Fig. 3(c).

This study addresses a technical challenge in monkey fMRI. Our method requires no additional information besides the original raw data. It is fully automated and can be used to retrospectively improve existing data sets. It has a good potential to allow more tolerance of monkey's body motion during fMRI. The possibility of a similar tuning for multi-shot EPI is a future research topic.

References

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