High Resolution GRE BOLD fMRI Using Multi-Shot Interleaved Spiral In/Out Acquisition

Y. Jung[1], T. T. Liu[1], and G. T. Buracas[1]
[1]Radiology, Univerisity of California, San Diego, La Jolla, CA, United States

INTRODUCTION

Blood oxygenation level dependent (BOLD) fMRI has been widely used for mapping brain function noninvasively. Recent dramatic advances in multivariate brain fMRI ("brain reading" and information-based brain mapping) depend on the availability of high spatial and temporal resolution acquisition methods. High resolution also affords increased BOLD contrast due to reduced partial volume effects and more accurate localization of BOLD activation. However, current standard acquisition methods for human brain BOLD fMRI typically have relatively low spatial or temporal resolution. An interleaved spiral in/out acquisition technique has recently been introduced by Law & Glover [1]. We developed this technique further by introducing an efficient multi-shot interleaved spiral in/out acquisition for BOLD fMRI. We tested this technique using visual and memory tasks. The proposed high resolution fMRI technique shows excellent activation with large spatial coverage. The new technique offers a benefit of larger spatial coverage and reduced susceptibility artifact as compared to the conventional EPI method.

THEORY

Fig. 1 shows the pulse sequence diagram and trajectory maps of 2D multi-slice multi-shot interleaved spiral in/out trajectory (spiral-in portion is in blue and the 180° rotated spiral-out portion is in red). The spiral in and out parts are interleaved for shorter echo time and improved data acquisition efficiency [1]. Because the interleaved spiral in/out acquisition can provide higher k-space acquisition efficiency and lower gradient duty cycle, it can cover larger slice coverage or higher temporal resolution than conventional EPI. Interleaving of spiral-in and –out parts generates image artifacts due to T_2^*, off-resonance, and k-space errors. To remove the artifact the trajectory direction is switched every other frame and per-voxel based spectral filtering is applied to remove these artifacts [2,3]. To achieve high resolution fMRI, a multi-shot technique is required to set a TE to optimum value (~30ms). For multi-shot acquisition, the ith trajectory at jth time frame is rotated with an angle of $(i/N+\mathrm{mod}(j,2))\pi$, where N is the number of interleaves for whole k-space coverage.

METHOD

Images were acquired from subjects performing a visual task and a memory task with the proposed multi-shot interleaved spiral in/out method. The experiment was executed on a 3T Signa HDx scanner with an 8-channel head coil (GE Healthcare, Waukesha, WI). The two tasks were as follows:

- ·Visual task: a single run of block design with 8-Hz flickering checkerboard (40s off, 4 cycles of 40s on/20s off). TE: 31ms, TR: 1s, volume TR: 4s, FOV: 24cm, slice number: 15, imaging matrix: 256x256, spatial resolution: 0.94x0.94x2mm.
- ·Memory task: a single run of block design with *familiar* (*f*) and *novel* (*n*) scene pictures (30s *f*, 4cycles of 30s *f*/30s *n*). TE: 30ms, TR: 1.5s, volume TR: 3s, FOV: 24cm, slice number 24, imaging matrix: 164x164, spatial resolution: 1.46x1.46x1.4mm.

Physiological noise correction was performed using cardiac and respiratory data collected during the scan with a method based on RETROICOR [3]. Activation maps (p<0.01) were generated from the corrected data and no smoothing was applied.

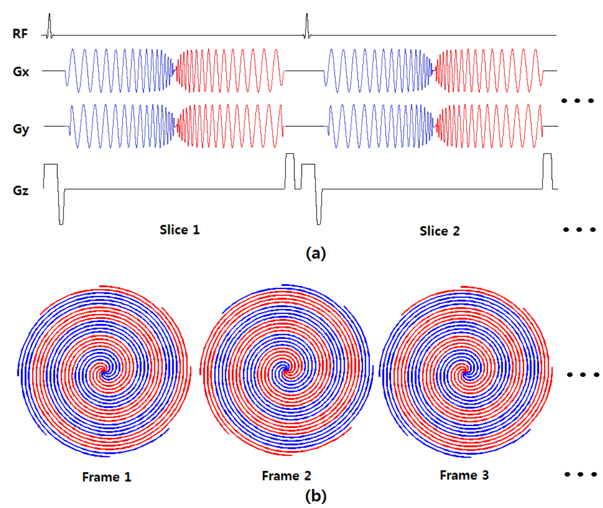

FIG.1. Pulse sequence diagram for the multi-slice multi-shot interleaved spiral in/out (a). Spiral-in and-out parts are interleaved with respect to each other. Multi-shot ordering schemes (4 shots) (b). The trajectory directions are reversed in the next frame.

RESULTS

Fig. 2 shows the activation maps for the two tasks. For both tasks the activation areas are well localized within the gray matter and show excellent SNR despite the absence of smoothing. The proposed method yields homogenous, high SNR activation by visual stimulus throughout the range of early visual cortical areas (left). A robust cluster of activity in the parahippocampal gyrus (right) evoked during a memory task indicates that the proposed technique can be used for high-resolution cognitive brain imaging. In summary, the proposed method provides slice coverage and temporal resolution superior to the conventional high resolution EPI.

REFERENCES

1. Law and Glover, MRM v63: p829, 2009.
2. Madore and Glover, MRM v42: p813, 1999.
3. Glover et al. MRM v44: p162, 2000.

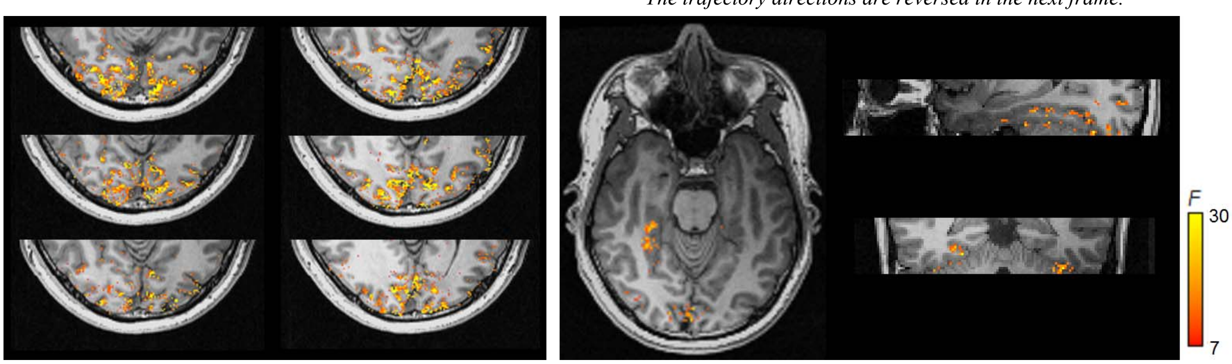

FIG. 2. Activation maps (p<0.01) evoked using visual stimulus were acquired at high spatial resolution (0.94x0.94x2mm³) (left). Six contiguous slices out of 15 are shown. Activation areas are well localized in the occipital lobe. Activation maps (p<0.01) at three orthogonal planes from the memory task at high resolution (1.46x1.46x1.4mm³) (right).Well-defined activation can be observed in the parahippocampal gyrus.