T2 and T2* Triple Spiral Acquisition for fMRI on 3T Systems

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Introduction

Brain regions at air-tissue interfaces, such as the orbitofrontal cortex (OFC), often suffer from severe signal loss (susceptibility artifacts) in gradient-echo based BOLD fMRI studies, especially on high-field such as 3T systems. The gradient-echo based spiral-in/out acquisition technique proposed by Glover et al. has shown an advantage in increasing signal-to-noise ratio (SNR), and in reducing susceptibility artifacts (1), and has been applied for studies in these regions (2). Spin-echo based techniques, although less sensitive than gradient-echo based techniques at lower fields, have also been shown to be valuable for fMRI studies on 3T systems in regions suffering from severe susceptibility artifacts. Spin-echo techniques also offer potential for more precisely localizing brain activity due to the higher BOLD sensitivity in the order of capillary size (3). A triple spiral acquisition technique is proposed here to take advantage of the benefits of both the spin-echo and spiral-in/out acquisitions without sacrificing additional temporal/spatial resolution.

Methods

This triple spiral sequence (Fig. 1) has been designed with the consideration that good BOLD contrast on a 3T system can be obtained for spin-echo acquisition at approximately 70 ms TE and for gradient-echo acquisition at approximately 30 ms TE. A 180° refocusing RF pulse is applied between the first two spirals. T_2* weighted images are acquired by the first two spirals with TE_1, with the effect of spin refocusing at the latter part of the 2nd spiral. The T_2 weighted images are acquired through the 3rd spiral. The impact of the static local field inhomogeneity is expected to reduce in all three spiral acquisitions.

All studies were carried on a 3T GE Signa MR imager to acquire 18 5-mm-thick axial slices with a 2 s TR, with a TE of 28 ms for the traditional single spiral out (SS), 30 ms for the in/out dual spiral (DS), a TE_1 of 29.5 ms and a TE_2 of 67.6 ms for the triple spiral (TS). Flip angles were 77° for SS, and 90° for both DS and TS. Signal recovery was compared based on T_2 and T_2* images at the frontal region. Its applicability to fMRI was first evaluated through simple ON-OFF index finger tapping studies of both hands with motor cortex activation: A protocol of 12 s resting and then 24 s finger tapping was repeated 24 times for both the TS and SS acquisitions.

Results

Comparing to the SS or the out spiral of the DS, signal recovery is seen in the frontal regions for all three spiral acquisitions of the TS technique with 3rd > 1st > 2nd spiral in terms of effectiveness (Fig. 2). In the finger-tapping study, activation at the motor cortex is seen in all three spirals of the TS technique. As expected in spin-echo based acquisitions, there is a reduced number of active voxels with the 3rd spiral of the TS technique.

Discussion

The availability of three signals acquired through the TS sequence at each time point also offers an opportunity of improved sensitivity. A multivariate analysis technique (4) can be applied to utilize the benefits of the three different BOLD contrasts available. The applicability of the triple spiral sequence will be further evaluated through the study of OFC activation using emotionally arousing pictures.

References

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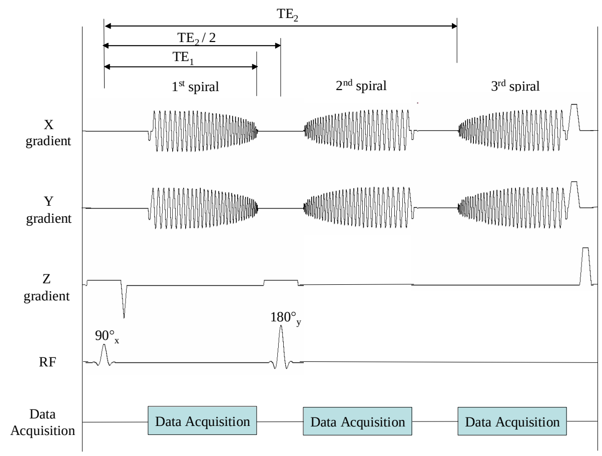

Fig. 1. The triple spiral sequence. Three separate images are acquired while the X and Y spiral gradients are applied. A 180° RF focusing pulse is applied between the first two spiral acquisitions.

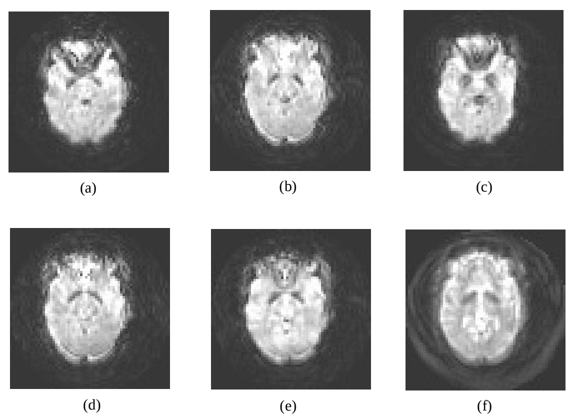

Fig. 2. Image signal loss comparison: (a) SS (out spiral), (b) in spiral of DS. (c) out spiral of DS, (d) 1st spiral (in) of TS, (e) 2nd spiral (out) of TS, (f) 3rd spiral (out) of TS.

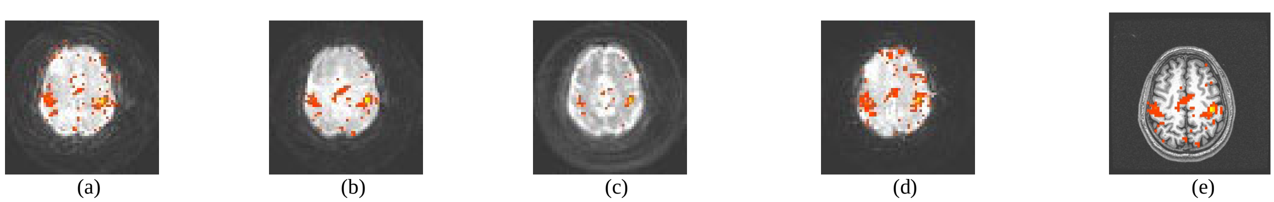

Fig. 3. Finger-tapping motor study comparison: (a) 1st spiral (in) of TS, (b) 2nd spiral (out) of TS, (c) 3rd spiral (out) of TS, (d) SS (out spiral), (e) T_1 weighted, overlaid with activation from 2nd spiral (out) of TS.