Self Calibrated Spiral-In/Out for fMRI

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Introduction. In-plane image resolution in BOLD functional magnetic resonance imaging (fMRI) is limited by susceptibility-induced signal dropout and off-resonance artifacts. Although higher spatial resolution can be achieved with multi-shot sequences, increasing the number of shots reduces temporal resolution. We propose an auto-calibrated multi-shot interleaved spiral-in/out sequence in conjunction with parallel imaging to improve spatial resolution while maintaining the desired temporal resolution. Temporal resolution is maintained by reconstructing one frame of image using only partially acquired k-space data through the iterative SENSE algorithm. Sensitivity auto-calibration is achieved by combining consecutive frames of data to reconstruct a fully sampled image. A two-shot sequence is demonstrated with a breath-hold activation experiment. Compared to the conventional one-shot technique, SENSE reconstruction improves image quality and significantly increases activation in areas of severe susceptibility artifacts.

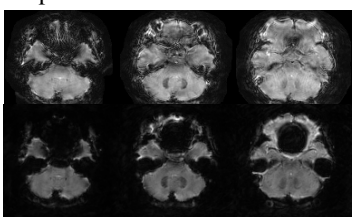
Methods. In the two-shot experiment, the spiral-in/out trajectory for the second shot is rotated by 180 degrees. Its readout duration is about half that in single-shot. For every two shots, the spiral-in data is used to construct a spiral-in image; likewise for spiral-out. (1) These two-shot images are used to compute sensitivity profiles. No extra calibration scans are needed. For fMRI in brain where cerebral cortex stays relatively stationary, high SNR sensitivity-profiles can be calculated by averaging all two-shot images. (2) The PI reconstruction technique we used is Conjugate Gradient SENSE (CG-SENSE), from which one spiral-in image and one spiral-out image is acquired in every repetition time (TR). (3) For comparison of image quality and activation volume, a single-shot spiral-in/out experiment is also performed.

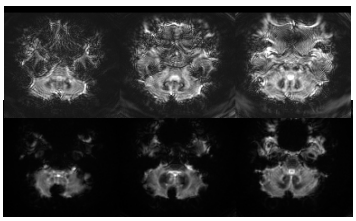
A breath-holding activation experiment is carried out on a GE 3T scanner. This task consists of 15s normal breathing and 15s breath-holding after inspiration, visually cued and repeated for 8 cycles. This causes a systemic hypoxia resulting in BOLD signal modulation, independent of cognition, having a trough during breath-holding epochs. (4) Four oblique slices (128x128) were gathered using an 8-channel head coil (TR/α/TH/FOV=1s, 70°, 5mm, 20cm). TE is set to be minimal (66.2 ms for single-shot, 35.4 ms for 2-shot). Single-shot data is reconstructed as sum of squares for each coil. Two-shot data is reconstructed first conventionally, for calculating sensitivity profiles, then using CG-SENSE to make high spatial- and temporal-resolution images. Navigator correction is applied to all data. (5) Due to signal magnitude inconsistency between shots, time series intensity in CG-SENSE-reconstructed images fluctuates. Temporal filtering with a width of Nyquist/16 is used to remove this fluctuation artifact. (6)

Correlation analysis is performed by cross-correlating image time-series for each pixel with sine and cosine functions at the fundamental task frequency. Activation volume is compared between single-shot images and two-shot images reconstructed with CG-SENSE. Voxels with t-statistics above 2.5 are considered activated.

Results. Magnitude images of spiral-in and spiral-out from the two experiments are shown in Figure 1. Note the amount of signal dropout and distortion in single-shot trajectory. Correlation analysis becomes difficult in those regions. Figure 2 shows typical t-statistic maps. Activation voxels from two-shot CG-SENSE data are more localized in the expected gray-matter regions.

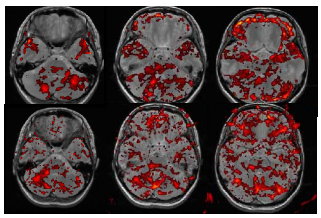
Discussion. Using spiral-in/out trajectory in PI-fMRI, we demonstrated that high spatial- and temporal-resolution images can be made having less susceptibility-induced signal-dropout. No extra calibration scans are needed to generate fully sampled sensitivity profiles. Thanks to its short readout duration and short TE, activation during a breath-holding task is detected in the medial temporal lobe by this technique. This technique is particularly applicable to high resolution imaging in areas like amygdale and orbitofrontal cortex where signal dropout is severe.

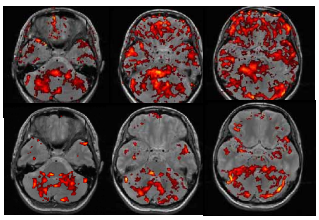




CG-SENSE single-shot

Fig. 1. Magnitude images. (Upper) Spiral-in images. (Lower) Spiral-out images.

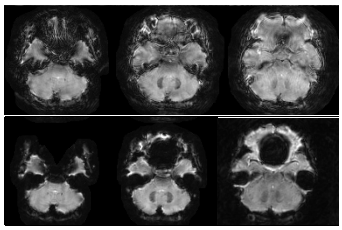




CG-SENSE single-shot

Fig. 2. Correlation coefficient images. (Upper) Spiral-in images. (Lower) Spiral-out images.

Reference. 1. Glover et al., Magn Reson Med. 2001; 46:515-22. 2. Lin et al., Magn Reson Med. 2005; 54:343-353. 3. Liu et al., Magn Reson Med. 2005 ; 54(6) :1412-1422. 4. Kastrup et al., Magn Reson Med. 1999; 42(3):608-611. 5. Le et al., Magn Reson Med. 1996: 35:290-298. 6. Madore, Magn Reson Med. 2002; 48(3):493-501.



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