Motion-insensitive structural MRI based on Repeated Imaging with Echo-planar Navigation and Acceleration (RIENA): Demonstrated with susceptibility-weighted imaging in the presence of frequent intra-scan tremors

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INTRODUCTION

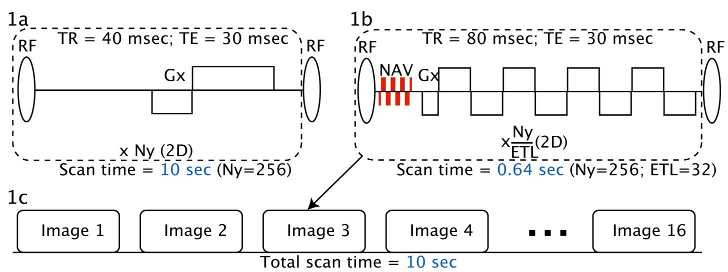
Most existing structural MRI pulse sequences are highly susceptible to motion related artifacts. As a result, it is challenging to acquire high-quality structural MRI data from certain subject populations, such as patients with tremors due to Parkinson's disease. It is therefore important to design improved data acquisition and reconstruction strategies, so that high-quality clinical MRI data can be reliably obtained from all patient populations.

Here we report a novel strategy to significantly reduce motion related artifacts in structural MRI, even in the presence of frequent intra-scan tremors. Our new approach, termed ***R**epeated **I**maging with **E**cho-planar **N**avigation and **A**cceleration (RIENA)*, can generally be applied to various structural MRI scans (e.g., T1-weighted imaging; and T2-weighted imaging among others) when appropriate magnetization preparation schemes are used. In this abstract we demonstrate the application of *RIENA* to significantly reduce motion related artifacts in susceptibility-weighted imaging (SWI: which is sensitive to motion due to its longer scan time) even in the presence of frequent intra-scan tremors.

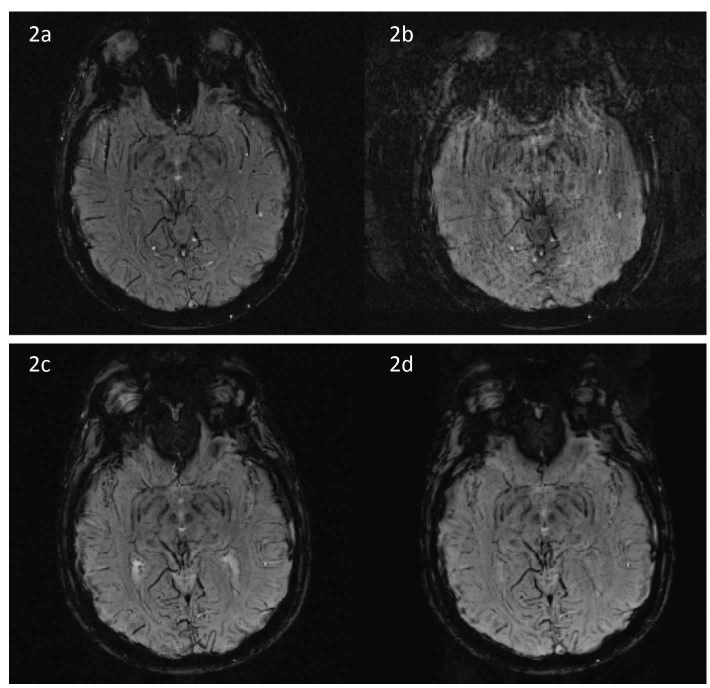
METHODS

Figures 1a and 1b-c schematically compare T2*-weighted SPGR and the RIENA pulse sequences, respectively, with their parameters optimized for SWI applications. In regular SPGR-based SWI, a low readout bandwidth (e.g., ~16 kHz) is chosen to improve the signal-to-noise ratio (SNR), and the unused time periods are significant, as shown in Figure 1a. As a result, the scan efficiency is usually low, and the scan time is long (e.g., ~ 10 sec per slice; with Ny=256 and TR = 40 msec) in SPGR-based SWI. In each TR of our RIENA sequence, an EPI based low-resolution navigator image (e.g., 16 x 16 matrix size: red gradient waveforms in Figure 1b) is first acquired. Multiple ky-lines of segmented high-resolution data are then obtained with echo-planar waveforms, with its echo train length (ETL) chosen to accelerate acquisition without introducing noticeable EPI geometric distortions. With this scheme, the acquisition time of RIENA can be significantly reduced (e.g., 0.64 sec per slice; with Ny=256, ETL=32 and TR = 80 msec) as compared with 2D SPGR. As shown in Figure 1c, the RIENA pulse sequence can be repeatedly used to acquire multiple images within a fixed scan time (e.g., 16 sets of images within 10 sec).

Multiple images obtained with the RIENA pulse sequence are processed with the following procedures to minimize motion related artifacts. First, low-resolution EPI navigator images measured across multiple TRs are compared to characterize the patterns of intra-scan motion. Second, the acquired k-space data in each TR period (i.e., corresponding to a single segment of 8-shot segmented EPI) are phase-corrected using the information derived from EPI navigators. Third, multiple phase-corrected images are then averaged to generate an image with high SNR. Note that the residual ghost artifacts are incoherent across TRs, and thus can be further reduced when averaging multiple complex-RIENA images.



We have experimentally compared the SPGR- and RIENA-based SWI data, with and without the presence of intra-scan motion, in healthy volunteers. The subjects were asked to remain very still for the first set of SPGR and RIENA scans (10 sec for each). In the second set of SPGR and RIENA scans, the subjects had frequent voluntary tremors throughout the whole scans (~ 10 mm displacement at ~3 Hz). The reconstructed SPGR and RIENA images were then compared in terms of the SNR and motion related artifacts.



RESULTS

The upper and lower panels of Figure 2 compare the SPGR (a and b) and RIENA (c and d) images. First, without the presence of intra-scan motion (left column), SPGR (a) and RIENA (c) images have comparable quality, SNR and SWI contrast. Second, in the presence of frequent intra-scan tremors (right column), the SPGR image is corrupted by ghost artifacts (b). On the other hand, the image reconstructed with the RIENA algorithm (d) is free from noticeable motion related artifacts.

DISCUSSION

As compared with the conventional structural MRI sequences (e.g., SPGR), the developed RIENA technique has higher scan efficiency, making it possible to acquire multiple images within the same scan time. Using the embedded EPI navigator within each TR, the intra-scan motion can be characterized and used to phase-correct each k-space segment of multi-shot segmented EPI. Furthermore, the obtained multiple complex RIENA images can be averaged to enhance the SNR and to reduce the motion related artifacts that are incoherent across multiple TRs. Note that the RIENA sequence uses a longer TR and thus has a lower SAR value as compared with the SPGR. The proposed RIENA method can generally be applied to various structural MRI scans (e.g., T1-weighted and T2-weigthed among others) when appropriate magnetization preparation schemes are incorporated.