Reducing Motion Sensitivity in 3D High-resolution T_2^*-weighted and QSM MRI By Navigator-based Motion and Nonlinear Magnetic Field Correction

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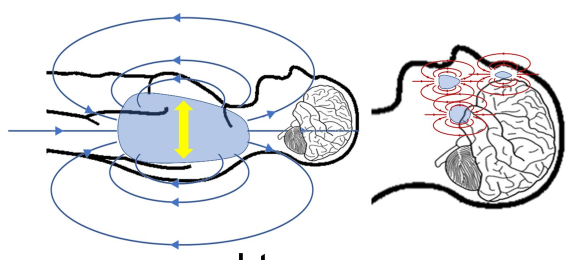
Advanced MRI

Introduction

- T_2^*- or susceptibility-weighted MRI provides clinically relevant information about the iron and myelin content in the brain.
- These techniques are sensitive to motion and motion-related B_0 changes, which complicate their use for clinical practice.
- Correcting for pose-dependent B_0 field changes has not been addressed in conventional MRI motion correction.
- In this study, a navigator (built on MR signal)-based approach was proposed to simultaneously correct for motion and B_0 field changes in T_2^*-weighted GRE.

Susceptibility sources causing pose-dependent B_0 distribution



Methods

❑ Navigator for motion & B_0 measurement

- STEEN: Short TE (echo time) volumetric EPI Navigator
- Acquired STEEN signal in parallel with high-resolution T_2^*-weighted GRE data
- Accelerated STEEN with parallel imaging
- Temporal resolution of 0.54 s at 4 mm resolution with a FOV of 240x192x96 mm³ and TR of 45 ms

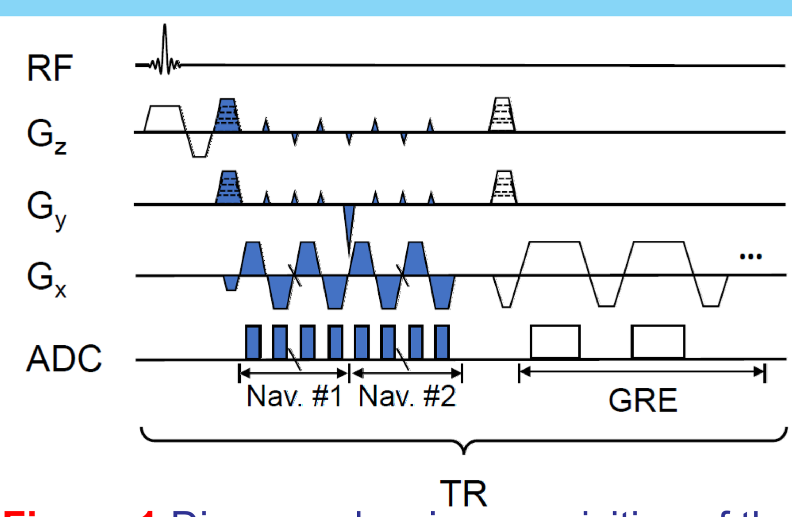


Figure 1 Diagram showing acquisition of the STEEN navigator preceding the high-resolution T_2^*-weighted GRE data in each TR

❑ Image correction

- Corrected GRE images in the reconstruction retrospectively with STEEN-measured motion and B_0 change information
- Developed a fast clustering-based retrospective algorithm to compensate for the nonlinear component in the B_0 changes
    - Clustered the GRE data based on the STEEN-measured B_0 to correct for the nonlinear B_0 changes across clusters, and motion and linear B_0 changes within each cluster using the fast NUFFT algorithm[1]
    - Needed less than 10 clusters (determined automatically based on the B_0 data) in all cases in this study

❑ Experiment design & data analysis

- 7 T MRI (Siemens) with 32-channel head RF coil (Nova Medical)
- Evaluated STEEN accuracy for measuring motion and B_0 changes using concurrently measured GRE
    - Changed head pose in-between scans without intra-scan movement
    - Isotropic 2 mm resolution GRE with isotropic 4 mm and 6 mm (downsampled from the 4 mm) resolution STEEN for evaluating STEEN accuracy (3.5-minute long)
- Evaluated the correction performance on GRE images acquired with intentional motion
    - Performed head movement guided by visual cues during scans
    - 0.5x0.5x1.5 mm³ resolution GRE with TE=26 ms for correction (9.5-minute long)
    - Reconstructed quantitative susceptibility maps (QSM) based on the GRE phase[2]
    - Evaluated the corrected images in reference to the images from a separate scan without intentional motion

Results

❑ Accuracy of STEEN for measuring head motion and B_0 changes

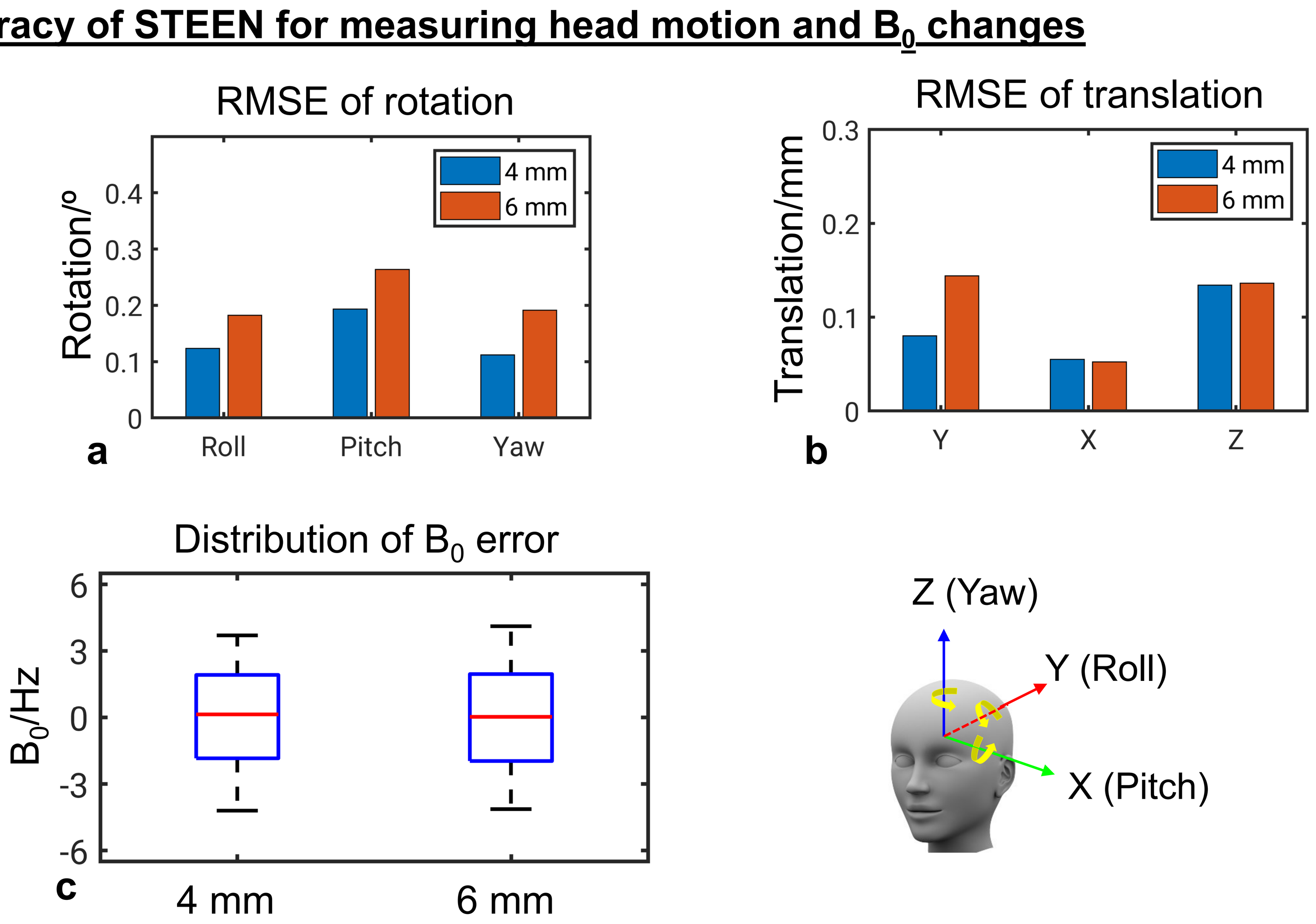


Figure 2 Root mean square error (RMSE) (a and b) and error distribution (c) of STEEN-estimated motion and B_0 changes, respectively (N=6), for 4 and 6 mm isotropic resolution STEEN. In (c), bars indicate the 2.5-97.5% percentile interval and boxes the 10-90% percentile interval.

Results

❑ Correction performance across all subjects

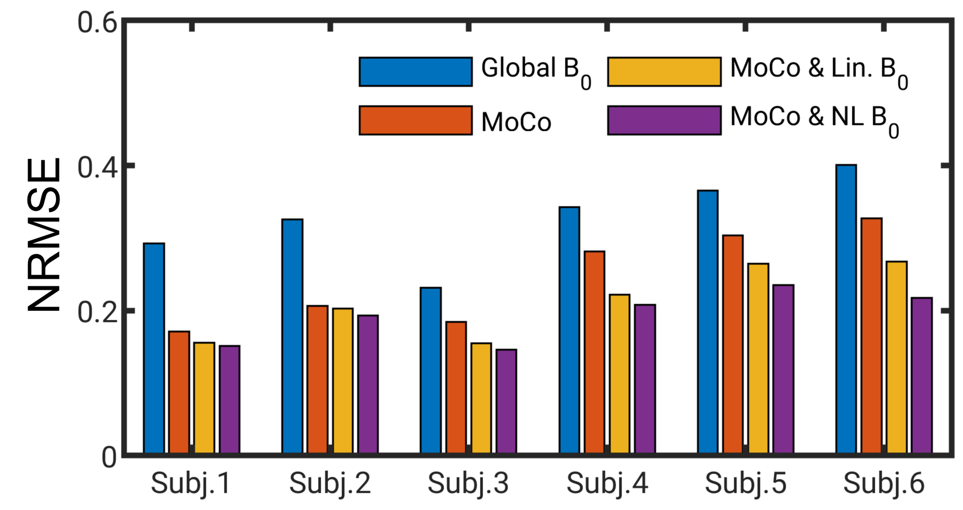


Figure 3 Improvement using motion and more sophisticated B_0 correction across all subjects (N=6) as quantified by the normalized root mean square error (NRMSE) of the corrected GRE magnitude relative to the reference GRE magnitude. STEEN at 4 mm resolution was used.

❑ Examples of corrected GRE and QSM

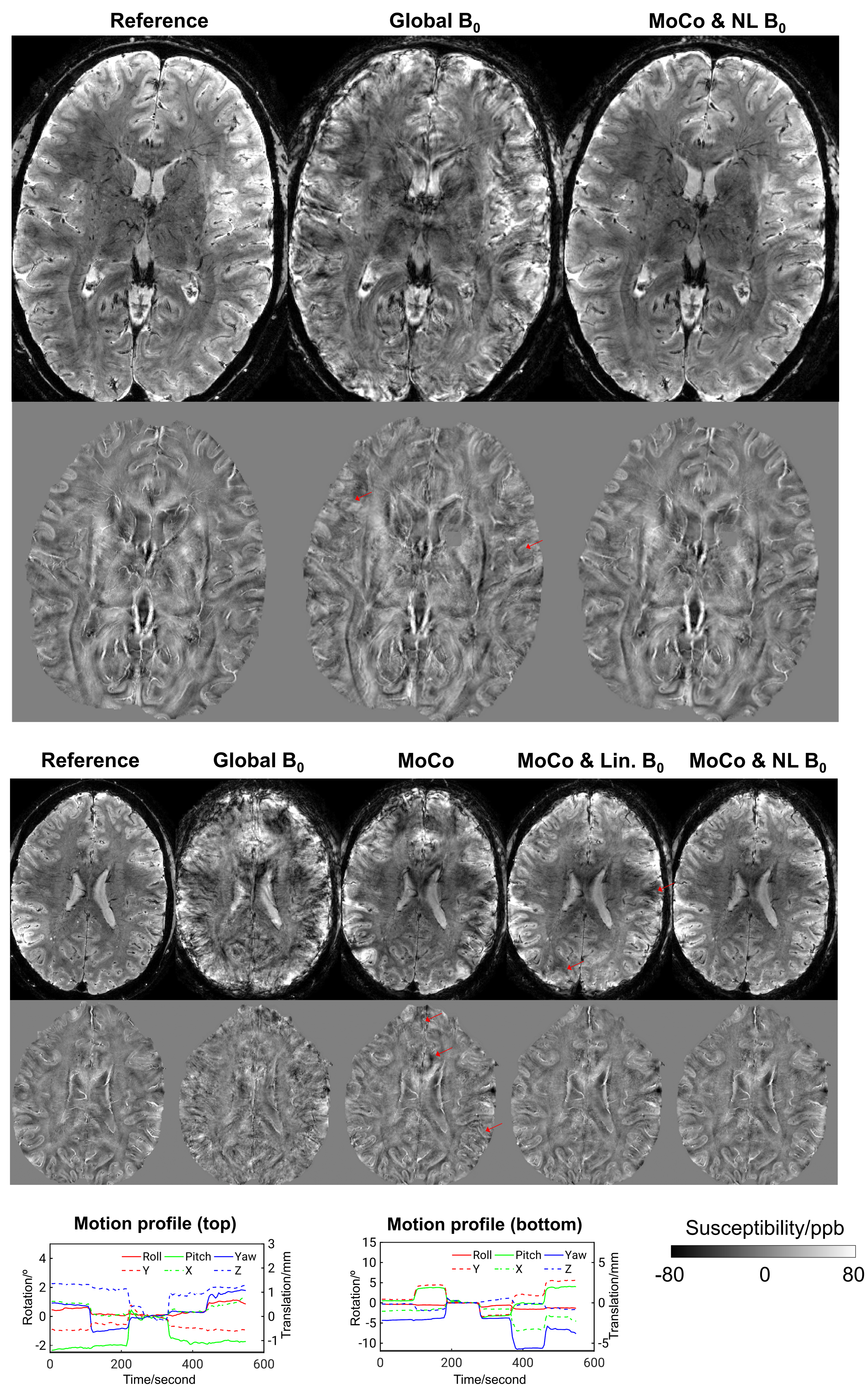


Figure 4 T_2^*-weighted GRE magnitude (first row) and QSM (second row) under different correction modes from Subject 4 (top) and Subject 6 (bottom): *Global B_0* — zero-order B_0 correction, *MoCo* — motion correction, *MoCo & Lin. B_0* — motion and linear B_0 correction and *MoCo & NL B_0* — motion and nonlinear B_0 correction.

Conclusion

- Developed a Short TE EPI volumetric Navigator (STEEN) with high temporal (~0.5 s) and spatial resolution (4 mm) for measuring head motion and B_0 changes in 3D T_2^*-weighted GRE
- Demonstrated high accuracy of STEEN for measuring motion (0.2º/0.1 mm) and B_0 changes (2 Hz@7T)
- Implemented a fast motion and nonlinear B_0 correction algorithm in the GRE reconstruction
- Significantly reduced artifact in high-resolution T_2^*-weighted GRE and QSM using the proposed method

Reference [1] Fesslor and Sutton. *IEEE Trans Signal Process*. 2003 [2] Özbay et al., *NMR Biomed*, 2015

This poster is available at https://amri.ninds.nih.gov/presentations/2019/liuj23.qsm.pdf