Collapsed FatNav - A 3D Motion Navigator Using the Chemical Saturation RF-pulse

Mathias Engström[1,2], Magnus Mårtensson[1,3], Ola Norbeck[2], Enrico Avventi[1], Axel Hartwig[2], and Stefan Skare[1,2]

[1]Clinical Neuroscience, Karolinska Institutet, Stockholm, Stockholm, Sweden, [2]Neuroradiology, Karolinska University Hospital, Stockholm, Stockholm, Sweden, [3]EMEA Research and Collaboration, GE Applied Science Laboratory, GE Healthcare, Stockholm, Sweden

Purpose

To investigate the use of the fat signal from a standard chemical saturation RF-pulse for prospective rigid-body motion correction, by adding three orthogonal, highly accelerated, 2D-EPI readouts.

Introduction

Involuntary patient head motion is one of the leading sources of artifacts in clinical neuro imaging, commonly requiring rescans due to corrupted images. For certain type of pulse sequences (e.g. PROPELLER, EPI), retrospective motion correction techniques often works well, but spin-history effects from out-of-plane motion cannot be addressed and blurring effects due to retrospective resampling remains an issue. Prospective motion correction avoids these problems, by e.g. using some additional navigator data to track motion in real-time. In this work, we propose a new 3-plane projection navigator relying on the fat signal from a standard (non-slice selective) chemical saturation ('fat-sat') RF-pulse used for many clinical fat-saturated pulse sequences. With three orthogonal EPI readouts placed after the fat-sat pulse, navigator data is read out before the spoiler gradient prior to the main sequence. To minimize the duration of this navigator, the use of high GRAPPA acceleration factors was investigated. Six experiments were carried out to test if continuous motion could be detected in three orthogonal scan planes using the proposed navigator, and to investigate the overall jitter in the absence of motion.

Methods

A healthy volunteer was scanned on a 3.0 T clinical MRI system (GE DVMR750, GE Healthcare, Milwaukee) using an 8-channel head coil (Invivo Hi-Res Head Coil, Gainesville, USA). A test sequence was made, with the standard 'fat-sat' RF-pulse followed by the three orthogonal EPI readouts using the following parameters: FOV = 28 cm, matrix = 48x48, resolution 5.8x5.8 mm^2, and TR = 40 ms. GRAPPA acceleration factors of 4, 6 and 8 were attempted. The respective echo-times became $TE_{Sagittal}$ = 5.1/4.6/4.1 ms, TE_{Axial} = 10.1/8.3/6.7 ms, $TE_{Coronal}$ = 15.2/11.9/8.7 ms, for R = 4/6/8, respectively. Separate GRAPPA calibration scans were performed using the same test sequence, but with the acceleration factor replaced with the same number of EPI shots. This allowed the GRAPPA calibration data to match the scan data both with respect to data content (fat signal) and geometric distortions (k-space phase accruals). For R = 8, four experiments were carried out (Fig 3a-f), were the volunteer was first instructed to lie as still as possible (Fig. 3a-c), followed by pitch (Fig. 3d), yaw (Fig. 3e), and lastly roll motion (Fig. 3f). This was performed for 400 repetitions, respectively. The images were motion corrected (retrospectively for now) relative to the first image in the series using a sum-of-squares metric (2).

Results

Figure 2 shows the navigator images for three acceleration levels, R = 4, 6, and 8. No apparent parallel imaging artifacts (ghosting) can be seen even at R = 8, despite the use of only 8 receiver channels. Figure 3 shows motion estimates from the four different experiments, the first of which is without motion, shown in Fig. 3a-c for each of the three projections

Discussion

When a (non-slice-selective) fat-saturation module is added to a (diagnostic) sequence, the fat signal is spoiled to null prior to the RF excitation in the main sequence. Here we propose to use this fat signal for prospective motion correction before it is spoiled, by adding three orthogonal 2D-EPI readouts in between. As the fat-sat pulse is non-slice selective, reading out three orthog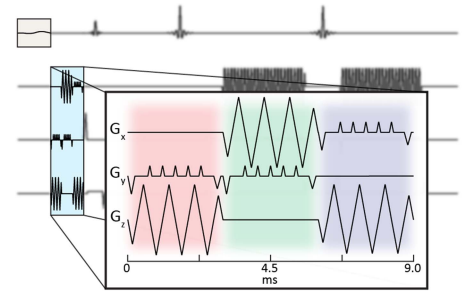onal 2D k-spaces results in projection images. The addition of the three EPI readouts, using R=8, adds only ~9 ms of total sequence time, but will not affect the TE for the main sequence. For e.g. a T2-w pulse sequence, having a sequence duration of ~250 ms, the time penalty for this is low. For a shorter sequences, this 9-ms EPI readout block may be added in front of every Nth excited slice to keep the total scan time down. Estimating head motion using fat-signal has presented recently (3,4), and in both cases, the sparse representation of the fat signal was emphasized. Through-plane, 'collapsed'/'projection', navigators has also recently been proposed using water signal (5), but required the entire stack of 2D slices of the main sequence to form a single collapsed navigator. Despite recent experience of attaining good image quality for sparse 2D FatNav images at very high reduction factors, it was not obvious that it would translate to this collapsed FatNav data. Yet, with a successful acceleration factor of eight on an 8-channel coil, we will now explore yet higher acceleration factors using 32-channel head coils. Most importantly, we will next implement this as a sequence plugin module with a real-time feedback loop for real prospective motion correction of diagnostic pulse sequences.

Conclusion

A new navigator technique has been proposed, intended for prospective motion correction of pulse sequences already using a fat-sat pre-pulse, where only three short orthogonal EPI readouts need to be added for low scan time overhead.

Figure 1 Schematic pulse sequence diagram (R = 8) showing the three orthogonal readouts of the navigator (Red - Sagittal, Green – Axial, Blue – Coronal)
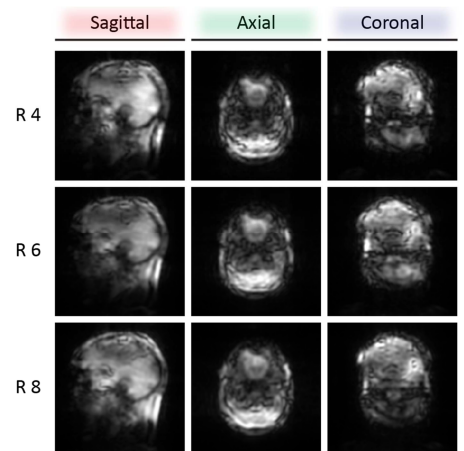

Figure 2 Acquired navigator data at R = 4/6/8. The sagittal data is from the first readout, the axial data from the second readout, and the coronal data from the third readout.
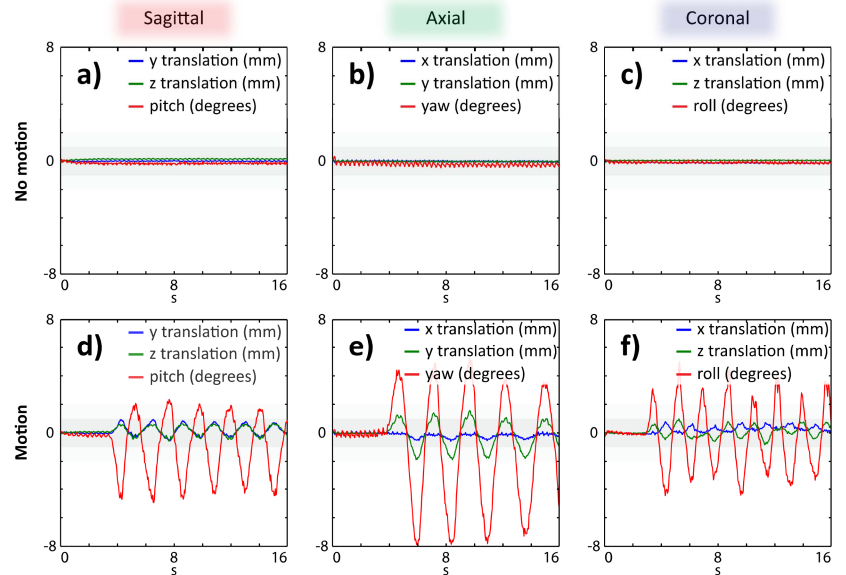

Figure 3 Motion estimates from the four experiments. No motion in the a) sagittal plane, b) axial plane, and c) coronal plane. d) pitch in the sagittal plane, e) yaw in the axial plane, and f) roll in the coronal plane.

References

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