Investigating the potential of highly accelerated FatNavs for dynamic shimming

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Introduction: Changes in magnetic field inhomogeneity during respiration can degrade image quality, especially in susceptibility-weighted or T2*-weighted imaging, motivating research into navigators able to track these changes and correct them [1]. Recent work [2] showed that fat navigators (FatNavs) can be used for motion correction of head scans, exploiting the natural sparsity of the fat image to allow higher acceleration factors than water images, with the additional advantage that the fat-excitation leaves the water signal of the host sequence unperturbed. Here we investigate the possibility of using a highly accelerated double echo sequence as a full 3D navigator which is sensitive to the time-varying magnetic field and could potentially be implemented in a dynamic shimming scheme.

Methods: Imaging was performed using a Siemens 7T head-only MR scanner and a 32-ch RF coil (Nova Medical Inc.), we scanned a healthy volunteer who was asked to remain still during the scan. The double echo 3D-GRE with 3mm isotropic resolution, $TE_1/TE_2/TR$= 1.01/1.77/3.0 ms, 6/8 partial Fourier for both PE directions, 3x3 GRAPPA acceleration, TR_{volume}=210ms was repeated for 512 volumes over 2 minutes, separately for both fat-selective and water-selective excitation. Auto-calibrating lines for the GRAPPA reconstruction were measured only once, before all other scans. Data were retrospectively discarded to simulate increased undersampling factors, using multiples of 3 (the base-acceleration) up to 9x9 acceleration. In order to visualize the spatial distribution of the respiratory-induced field variations in the water images, we identified peaks and troughs of the mean B_0-field across the whole brain over time to allow calculation of a difference map. To simulate the efficacy of the navigators for tracking field changes over time, we performed a magnitude-weighted fit for the zeroth and first-order spatial terms, $B_0 = \beta_0 + \beta_x x + \beta_y y + \beta_z z$ – which would translate directly to dynamic shim correction-terms.

Results and Discussion: Figure 1 shows the B_0 map and the respiratory-induced ΔB_0 map, where the variation of approximately 8Hz across the brain is in agreement with previous measurements [3]. As expected, β_z is the dominant linear term, although respiratory-induced fluctuations in β_y of a smaller magnitude were also observed. Figure 2 shows reconstructed magnitude images at various acceleration factors for both water and fat acquisitions. Even at very high acceleration (6x9) the fat image exhibits only mild degradation due to undersampling artifacts – whereas the water image at the same acceleration is severely deteriorated. Figure 3 shows example time-courses over 15s of the fat acquisition, showing that the fitted shim-terms still closely follow the fluctuations due to respiration, even at 6x9 acceleration. Table 1 quantifies the correlation between the parameters estimated from the accelerated scans vs the ground truth (taken as the original 3x3 accelerated data). It would appear that acceleration of up to 6x9 would be feasible for the FatNavs, reducing TR_{volume} to 35 ms.

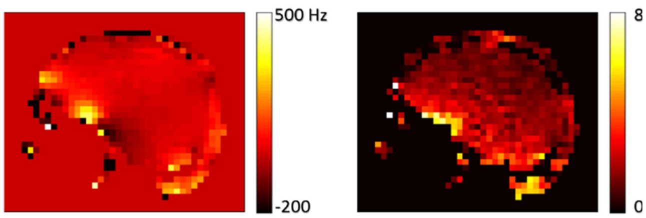

Figure 1: B_0 map (left) and ΔB_0 due to respiration map (right)

Acceleration	3x6	6x6	6x9	9x9
β_z correlation [%]	91	89	76	68
β_0 correlation [%]	91	87	78	74

Table 1: Correlation of estimated shim-parameters for different accelerations compared to ground truth (3x3 acceleration).

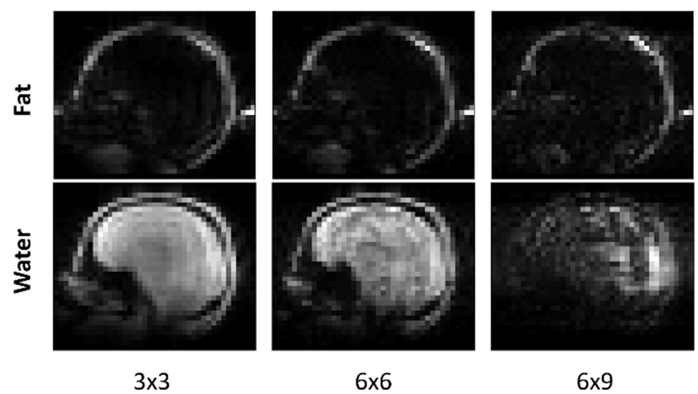

Figure 2: Water and fat magnitude images at different acceleration factors.

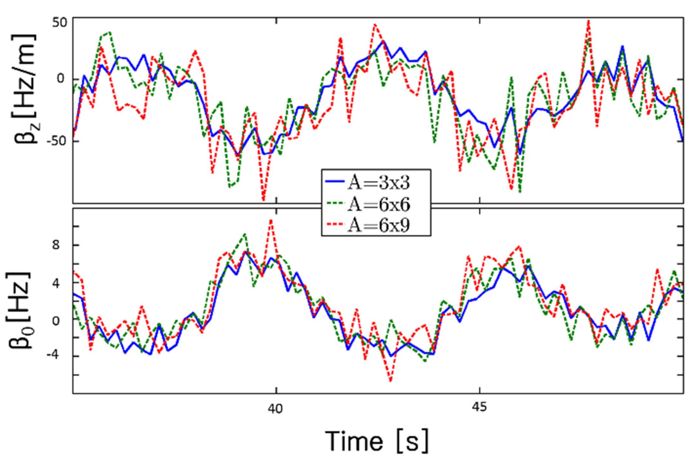

Figure 3: Example of shim-parameter time-courses for different accelerations.

Conclusion: We showed that highly accelerated FatNavs have the potential to provide accurate parameter estimates for dynamic shimming. Future work will explore applying the estimated parameters for retrospective shim-correction of 3D data. A sufficiently fast image reconstruction would also permit the FatNavs to be used for real-time shim updates.

References: [1] Versluis MJ et al, MRM (2012):68(6):1836; [2] Gallichan D et al, proc ISMRM 2014, p4345; [3] Van de Moortele P.-F. et al, MRM (2002) 47:888.

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