Increasing the SNR and Data Acquisition Efficiency of Displacement-Encoded MRI by the use of TrueFisp Imaging at 3T and TSENSE Parallel Imaging

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Introduction: Displacement-encoded MRI [1,2] is a promising method for quantifying 2D intramyocardial function with relatively high spatial resolution and without the need for explicit tag detection. However, it yields low signal-to-noise ratio (SNR) due to the 50% signal loss inherent to stimulated echoes and due to the SNR limitation imposed by the breath-hold duration for acquiring 6 data seta per image location (1 phase reference and 2 complementary displacement-encoded data sets per encoding direction [2]). A portion of the 50% signal loss can be recovered, by extracting two sub-sampled phase images with uncorrelated noise from a complex displacement-encoded data and combining them during image reconstruction, as previously described [3]. Phase subtraction of two sub-sampled phase images effectively cancels the background phase error, because the background phase for the two sub-sampled images is approximately identical. This inherent phase correction eliminates the need for acquiring additional phase reference images, as previously described [4], and potentially allows for the use of temporal filtering sensitivity encoding (TSENSE)[5] parallel imaging. The purpose of this feasibility study was to evaluate the use of TrueFisp imaging at 3T for increasing the SNR and TSENSE for reducing the acquisition time to a clinically acceptable breath-hold duration of 12 heart beats.

Methods: TrueFisp, displacement-encoded MR pulse sequence was implemented on a Siemens 3T Tim Trio system and subsequently used to scan a healthy volunteer in a mid-ventricular, short-axis of the heart, with and without TSENSE (acceleration factor =2). An informed consent was obtained. Imaging parameters included: field of view = 320 x 320 mm^2, acquisition matrix = 192 x 72, slice thickness = 7 mm, TE/TR = 1.7/3.3 ms, flip angle = 20°, bandwidth = 744 Hz/pixel, phase-encoding lines per cardiac phase per cardiac cycle = 12, and temporal resolution = 40 ms. The breath-hold durations were 12 and 24 heart beats for TSENSE and non-accelerated acquisition, respectively. The in-plane resolution, after sub-sampling, was 3.3 x 3.3 mm. Displacement was encoding along the frequency-encoding direction using two 90° RF pulses and a gradient pulse that yielded displacement-encoding frequency of 0.15 cycles/mm. Linearly increasing startup flip angles were used to reduce the osccilation of steady state interruption caused by the tagging/displacement-encoding pulses [6]. The resulting magnitude and phase images were reconstructed and analyzed off-line using Matlab (Mathworks), as previously described [3]. 2D phase unwrapping was performed by the use of a minimum-cost-match algorithm [7]. Endocardial and epicardial contours of the left ventricle (LV) were manually segmented, and the resulting LV mask image was divided into 6 sectors for analysis. The SNR and circumferential shortening strain (Ecc) measurements were computed over multiple cardiac phases. The mean Ecc was plotted as a function of time for both the non-accelerated and accelerated data sets. Correlation statistics of Ecc measurements by the non-accelerated and accelerated data sets were calculated by performing linear regression analysis.

Results: Figure 1 show a qualitative comparison of mid-ventricular, short-axis images at end systole produced by the non-accelerated and TSENSE acquisitions: magnitude image, phase map encoded for motion along x, phase map encoded for motion along y, 2D vector displacement map, and Ecc map. These images suggest that strain caculation is essentially unaffected by TSENSE when phase correction is performed. The non-accelerated data yielded higher SNR than TSENSE data throughout the cardiac cycle, from early systole (41 vs. 32) to late diastole (17 vs. 13). Relative SNR (non-accelerated/TSENSE) decreased from 1.3 at early systole to 1.15 at late diastole. Figure 2 shows plots of mean Ecc as a function of time for both data sets and the magnitude of the difference in Ecc. For pooled data of 90 points, there was a strong correlation between Ecc measured by non-accelerated and accelerated data sets (slope = 0.91, intercept = -0.02, and R = 0.90).

Discussion: This feasibility study shows that a combination of TrueFisp imaging at 3T and TSENSE parallel imaging can be used to achieve good SNR and relatively short breath-hold duration (12 heart beats) for displacement-encoded MRI. Initial findings suggest that strain calculation is unaffected by TSENSE imaging. A more extensive study is necessary to validate the accuracy and precision of strain calculation yielded by TrueFisp, displacement-encoded MRI using TSENSE.

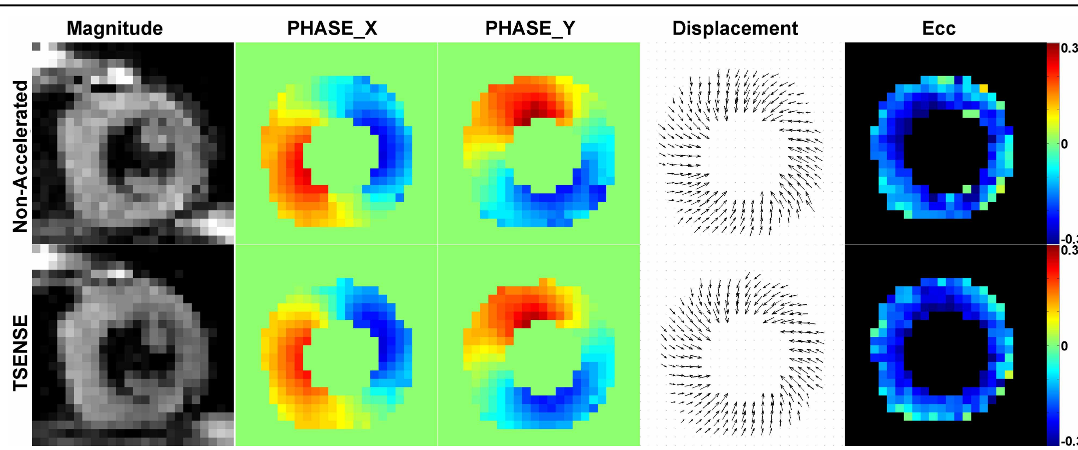

Figure 1. A magnitude image, a phase image for motion encoded along x, a phase image for motion encoded along y, a 2D vector displacement map, and an Ecc map of a mid-ventricular short-axis view of the LV at end systole for each data acquisition: non-accelerated (top) and TSENSE (bottom).

References
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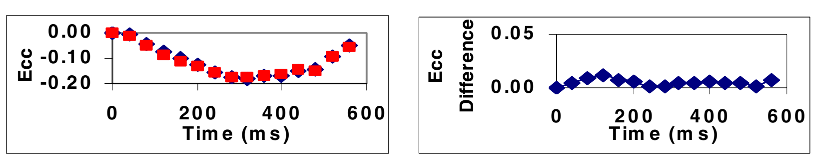

Figure 2. Plots of Ecc as a function time (left): non-accelerated (red square) and TSENSE (blue diamond). The magnitude of difference in Ecc (right).