Improved Cine Displacement-Encoded MRI using b-SSFP and TSENSE parallel imaging at 3T

Introduction: Displacement-encoded MRI [1,2] is a relatively high spatial resolution method for quantifying regional myocardial function, 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 a breath-hold acquisition of two orthogonal complementary spatial modulation of magnetization data sets per 2D strain analysis. The echo combination reconstruction method can be used to increase the SNR [3] and eliminate the need for acquiring phase reference images [4]. The purpose of this study was to further improve the SNR and data acquisition efficiency of cine displacement-encoded MRI through the use of balanced steady state free precession (b-SSFP) readouts and auto-calibrated temporal filtering sensitivity encoding (TSENSE)[5] parallel imaging.

Methods: Cine displacement-encoded MR pulse sequence using b-SSFP readouts (Fig. 1) was implemented on a Siemens 3T Tim Trio system equipped with a 12-channel phased array coil. We imaged six healthy volunteers in three short-axis views (apex, mid-ventricular, base) of the left ventricle, with and without TSENSE (acceleration factor = 2), in order to validate the image quality using the improved method. A written informed consent was obtained from each subject. Imaging parameters included: field of view = 320 x 320 mm2, 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 = 35 ms. The breath-hold durations were 12 and 24 heart beats for TSENSE and non-accelerated acquisition, respectively. The nominal spatial resolution was 3.3 x 3.3 mm. Displacement was encoded along the frequency-encoding direction using a frequency of 0.15 cycles/mm. Linearly increasing startup flip angles were used to reduce the signal oscillation caused by the interruption of steady state from tagging [6]. The resulting magnitude and phase images were reconstructed and analyzed off-line using Matlab (Mathworks), as previously described [2,3]. Endocardial and epicardial contours of the left ventricle (LV) were manually segmented, and the resulting LV was divided into 16 segments. Myocardial SNR and second principle strain (E2) were measured over multiple cardiac phases.

Results: The b-SSFP readouts at 3T yielded relatively high SNR throughout the cardiac cycle for both non-accelerated and TSENSE acquisitions (Fig. 2). The non-accelerated and TSENSE data sets were qualitatively similar for all subjects (Fig. 2), even though the former consistently produced higher SNR than the latter. Statically, E2 values measured by non-accelerated and TSENSE acquisitions were strongly correlated (slope = 0.99; bias = -0.00; R^2 = 0.91), and the measurements were in excellent agreement with a mean difference of 0.00.

Discussion: The combined use of b-SSFP and TSENSE parallel imaging at 3T yielded adequate SNR for displacement-encoded MRI. The use of TSENSE parallel imaging reduced the image acquisition time to a clinically acceptable breath-hold duration of 12 heart beats, without compromising the accuracy and precision of strain calculation. The use of a 32-channel cardiac array coil may further improve the performance of TSENSE for displacement-encoded MRI.

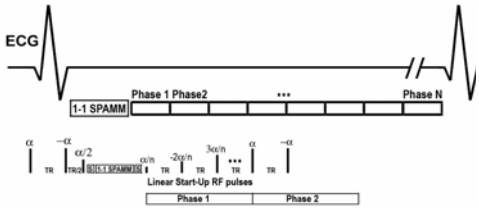

Figure 1. A schematic diagram of the ECG-gated displacement-encoded MRI pulse sequence using TrueFISP readouts. Linearly increasing startup flip angles were used to reduce the signal oscillation.

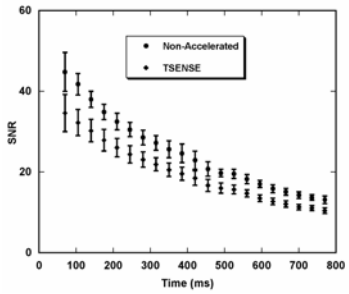

Figure 2. Plots of SNR as a function of time in one cardiac cycle.

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References

1. Aletras, AH, et al. MRM 46: 523-534 (2001).
2. Kim, D, et al. Radiology 230:862-71 (2004).
3. Kim, D, et al. MRM 52, 188-92 (2004).
4. Ryf, S, et al. JMRI 20: 874-80 (2004).
5. Kellman, P, et al. MRM 45:846-52 (2001).
6. Desphande, VS et al. MRM 46: 494-502 (2001).

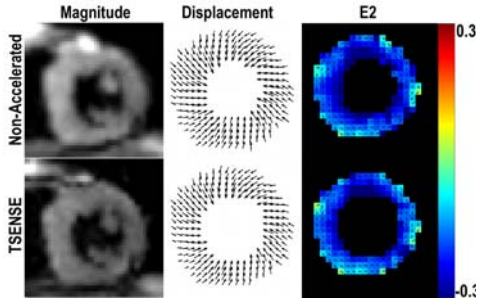

Figure 3. Representative data sets in a mid-ventricular short-axis view of the LV at end systole for non-accelerated (top row) and TSENSE (bottom row) acquisitions: (column 1) magnitude image, (column 2) 2D vector displacement map, and (column 3) E2 map.