Realtime Imaging of Regional Function of the Heart Using Fast-SENC at 3 Tesla

L. Pan[1], A. S. Fahmy[2], R. G. Weiss[3], A. Spooner[3], M. Stuber[4], N. F. Osman[4]

[1]Department of Biomedical Engineering, Johns Hopkins School of Medicine, Baltimore, MD, United States, [2]Department of Electrical and Computer Engineering, Johns Hopkins University, Baltimore, MD, United States, [3]Department of Cardiology, Johns Hopkins School of Medicine, Baltimore, MD, United States, [4]Department of Radiology, Johns Hopkins School of Medicine, Baltimore, MD, United States

Introduction: High field (≥3T) magnetic resonance imaging (MRI) systems have been demonstrated to offer better signal-to-noise-ratio (SNR) than that of 1.5T systems. Cardiac imaging, which has a high demand for temporal and spatial resolution, will especially benefit from the SNR improvement. However, the adverse effects coming with the increased field strength, such as increased B_0 inhomogeneity, increased susceptibility, reduced T_2*, and the power deposit limitations, make the cardiac imaging at 3T remain challenging.[1] Fast-Strain Encoded (Fast-SENC) imaging has been proposed as a technique that can image regional function of the heart in a single heart beat.[2] In this study, the feasibility to use fast-SENC imaging at 3T has been demonstrated. A fast-SENC imaging sequence with interleaved spiral acquisitions has been implemented on a 3T system to measure the regional function of the heart. The images were acquired both in normal subjects, and post-infarction patients with identified dysfunctional region compared with delayed enhancement imaging.

Methods: Fast-SENC pulse sequence Fig. 1 shows the fast-SENC imaging sequence implemented on a 3T whole body scanner (Achieva, Philips Medical System, Best, The Netherlands). Low tuning (LT) and high tuning (HT) acquisitions, required for fast-SENC imaging, were interleaved through the cardiac cycle. In order to reduce the FOV so that the sampled matrix size can be reduced in k-space, the two 90 degree tagging pulses were designed to only excite the region around the heart while suppressing the signal from untagged region.[2] To avoid the suffering from reduced T_2* and increased susceptibility at 3T, instead of using a relative long single spiral acquisition as in [2], multiple short interleaved spirals were used to acquire the whole k-space.[3] Experiments on human subjects Following informed consent, seven normal subjects (six males, one female) and five patients (four males, one female) with a history of myocardial infarction were imaged in both short-axis and four-chamber views. Fast-SENC images were acquired in one heart beat to cover the whole cardiac cycle. The imaging parameters were: slice thickness = 10mm, FOV = 256mm, Excitation Region Width (ERW, defined in [2]) = 180mm, matrix size = 64×64, spiral interleaves = 4, spiral acquisition window = 5ms, max ramped flip angle = 35. For post-infarction patients, after fast-SENC acquisition, intravenous contrast, 0.2 mmol.kg^{-1} Gd-DTPA, was injected. An inversion-recovery (IR)-prepared, fast field echo (FFE) pulse sequence with inversion time (TI) = 280-300ms was performed fifteen minutes after the injection to obtain a delayed enhancement image for the identification of the infarct region.

Results: Fig. 2 shows the cine functional images in a short-axis view acquired in one human subject. An increase of longitudinal strain on the left ventricle in systole and a decrease of that in diastole can be observed. Fig. 3 shows representative results of fast-SENC imaging from two patients in a four chamber view, with each row representing a different patient. A lack of contraction, shown as a decrease of circumferential strain measurement, at dysfunctional regions can be observed on fast-SENC images (Fig. 3 a,c). The area of dysfunctional regions closely matched the nonviable myocardium defined by hyperenhanced tissue in the delayed enhancement images (Fig. 3 b,d)

Conclusion: The fast-SENC imaging sequence has been demonstrated to be able to measure the regional function of the heart in a single heart beat in both normal subjects and post-infarction patients, despite the inherent challenges for cardiac imaging at 3T. The identified regional dysfunction of the heart in post-infarction patients show high agreement with those defined by delayed enhancement imaging. Fast-SENC shows its potential to dynamically detect the onset of ischemia during dobutamine stress test, or image the patients with cardiac arrhythmia.

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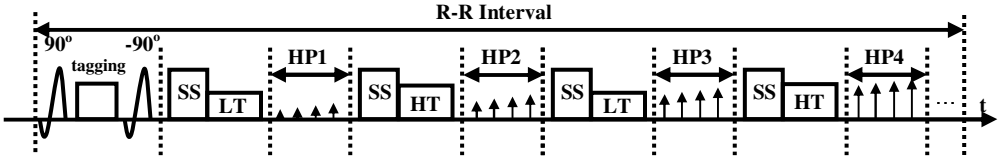

Fig. 1. Fast-SENC pulse sequence with interleaved spiral acquisition for each heart phase. SS = slice selection; HP = heart phase; LT = low tuning, HT = high tuning. Each arrow indicates a single spiral shot in k-space. Ramped flip angles were used to compensate for the tag fading caused by T_1 relaxation and maintain constant myocardial signal intensity throughout the cardiac cycle.

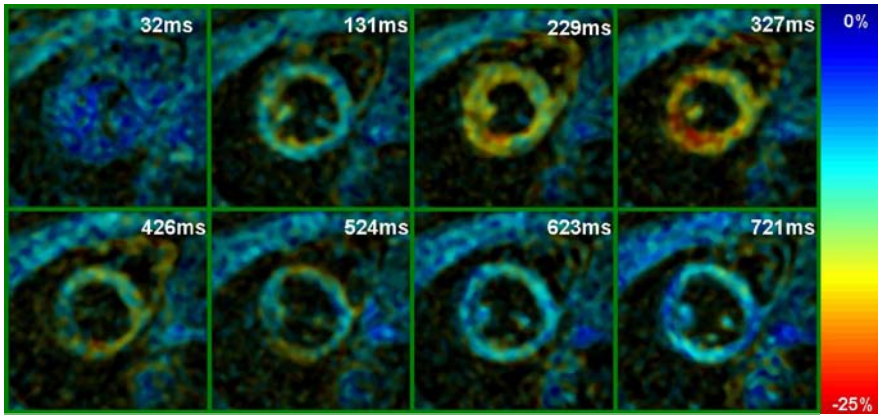

Fig. 2. Fast-SENC cine functional image sequence in short-axis view in a representative normal human subject, with a total of 17 timeframes (8 timeframes are shown) starting at end-diastole and covering the complete cardiac cycle.

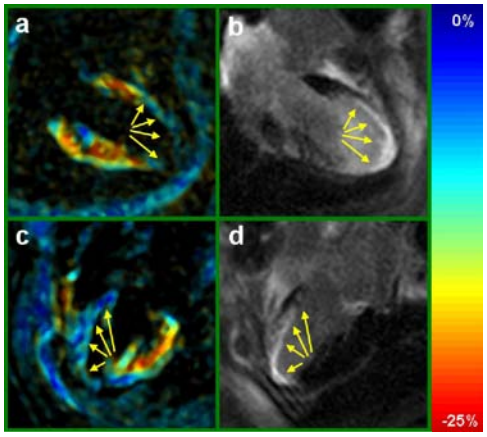

Fig. 3. Representative results from two post-infarction patients in four-chamber view. The fast-SENC functional images (a,c) showing regional dysfunction (arrows) were compared with the delayed-enhancement images (b,d) showing hyperenhanced nonviable infarcted myocardium (arrows).