Selective Suppression of Artifact-generating Echoes in Cine DENSE Using Through-plane Gradients

X. Zhong[1], E. A. Cowart[2], B. S. Spottiswoode[3], F. H. Epstein[4]

[1]Biomedical Engineering, University of Virginia, Charlottesville, VA, United States, [2]Engineering Physics, University of Virginia, Charlottesville, VA, United States, [3]MRC/UCT Medical Imaging Research Unit, University of Cape Town, Cape Town, Western Cape, South Africa, [4]Radiology and Biomedical Engineering, University of Virginia, Charlottesville, VA, United States

Introduction: Cine DENSE is a quantitative cardiac wall motion imaging technique where, in a time series of images, myocardial tissue displacement is encoded in the phase of the stimulated echo [1]. In practice, two or three echoes will contribute to the acquired signal in a basic DENSE experiment (the stimulated echo, the complex conjugate of the stimulated echo, and an echo due to T1 relaxation (Fig. 1B)) [1]. It is generally desirable to suppress all except the stimulated echo since failure to suppress the other echoes results in errors in displacement measurements. Furthermore, suppression of the artifact-generating echoes would ideally occur in a manner independent of time, T1, and displacement-encoding frequency, and without the need for additional acquisitions. Previously, numerous techniques have been developed for artifact suppression, including inversion recovery [2], CSPAMM [1], and CANSEL [3], but none achieve all of the desired properties. The purpose of the present study was to investigate using through-plane dephasing gradient pulses to selectively dephase the artifact-generating echoes without causing significant loss of signal to the stimulated echo.

Methods: Using a mathematical description of 2D DENSE [1], it is straightforward to show that application of identical gradient pulses applied in the through-plane direction during both the displacement encoding period and the readout period dephase both artifact generating echoes, but do not explicitly dephase the stimulated echo (however, they can cause signal loss of the stimulated echo in deforming tissue). Experimental data demonstrating selective echo dephasing in a stationary phantom are shown in Fig. 1. For breathhold *in vivo* studies, an EPI cine DENSE sequence [1] was modified to include through-plane dephasing gradients. Using this sequence, the spatial frequency created by the through-plane dephasing gradients could be varied, CSPAMM acquisitions could be performed, and a velocity-compensated flyback EPI *k*-space trajectory was used. Phase reference images were also acquired using the dephasing gradients to account for phase shifts attributable to through-plane motion. In accordance with protocols approved by our institutional review board, four volunteers were scanned using this sequence on a 1.5T MRI system (Sonata, Siemens Medical Solutions) after informed consent was obtained. The use of through-plane dephasing alone for artifact suppression was evaluated for single-acquisition cine DENSE. Also, through-plane dephasing was assessed for improved artifact suppression in CSPAMM-based DENSE, as CSPAMM alone is known to provide incomplete artifact suppression for *in vivo* imaging [1]. For each volunteer, the through-plane dephasing frequency was 0.15 cycles/mm for single acquisition DENSE and 0.08 cycles/mm for CSPAMM-based DENSE. Other imaging parameters included: FOV=225mm x 360mm, matrix=80x128, thickness=8mm, TR=22ms, TE=11ms, ETL = 7, flip angle = 20°, segments=14, and phases=18.

Results: Using through-plane dephasing alone, a complete cine DENSE data set with 2D displacement encoding could be acquired in half the time required for CSPAMM-based DENSE (16 heartbeats for the specific parameters used here). A dephasing frequency of 0.15 cycles/mm provided a balance between sufficient artifact suppression and myocardial signal-to-noise ratio (SNR) throughout systole. An example end-systolic displacement map from such data is shown in Fig. 2. Using through-plane dephasing with a frequency of 0.08 cycles/mm in conjunction with CSPAMM led to improved suppression of the T1-relaxation echo across the cardiac cycle compared to using CSPAMM alone (Fig. 3).

Conclusions: Using through-plane dephasing alone with relatively high dephasing values, good image quality could be obtained throughout systole using a single acquisition. However, SNR was poor in diastole. Using through-plane dephasing with CSPAMM and relatively low dephasing values, image quality was good throughout most of the cardiac cycle and artifact suppression was better than using CSPAMM alone. The judicious use of through-plane dephasing may improve artifact suppression in cine DENSE.

1. Kim et al. Radiology 2004; 230(3):862-871.
2. Aletras et al. MRM 2001;46:523-534.
3. Epstein et al. MRM 2004;52:774-781.

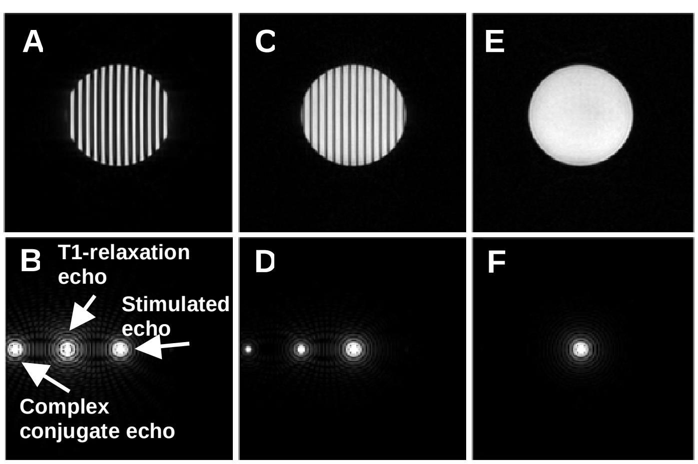

Fig. 1. Through-plane echo-selective dephasing in a stationary phantom. No dephasing is applied in (A, B), and both artifact-generating echoes are present and produce strong amplitude modulation in the image (A). Application of larger dephasing gradients selectively suppress the artifact-generating echoes to greater degrees, decreasing the amplitude modulation (C-F).

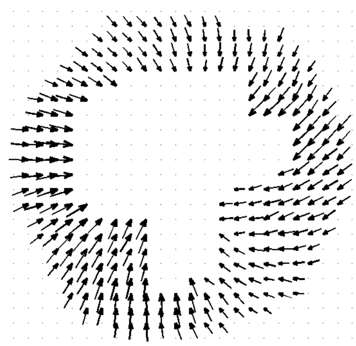

Figure 2. End-systolic 2D displacement map from a single-acquisition DENSE data set acquired using a relatively large through-plane dephasing gradient pulse (0.15 cyc/mm).

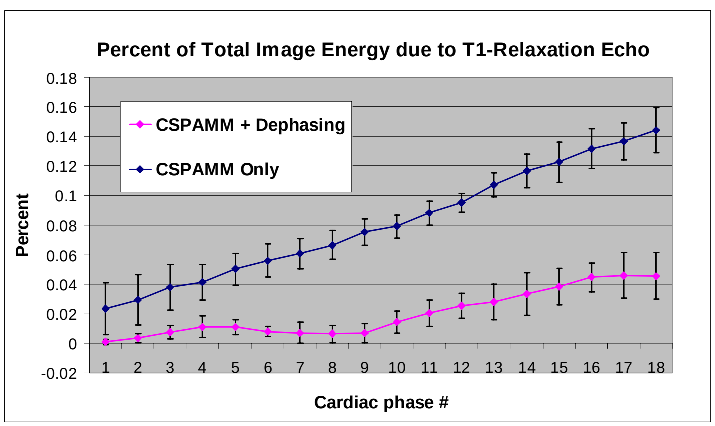

Figure 3. Percent of total DENSE image energy due to the T1-relaxation echo when using CSPAMM artifact suppression alone vs. using CSPAMM in conjunction with through-plane dephasing.