Spiral Cine DENSE MRI at 7T for Quantification of Regional Function in the Mouse Heart

X. Zhong[1], R. L. Janiczek[1], B. A. French[1], R. J. Roy[2], C. M. Kramer[2], C. H. Meyer[1], and F. H. Epstein[1,2]

[1]Biomedical Engineering, University of Virginia, Charlottesville, VA, United States, [2]Radiology, University of Virginia, Charlottesville, VA, United States

Introduction. Displacement encoding with stimulated echoes (DENSE) has previously been used on a 4.7T MRI system to quantify myocardial displacement and strain in the mouse heart (1). Due to limited signal-to-noise ratio (SNR), data acquisition for DENSE in mice has been limited to a single (usually end systolic) cardiac phase. Multiphasic data acquisition is preferable because (a) pre-estimating the time to end systole is imperfect, (b) the time to peak strain can vary with cardiac segment, and (c) multiphasic data allows for the accurate estimation of strain rate, as well as strain. The purpose of the present study was to develop a cine DENSE method with adequate SNR for high-resolution 2D imaging of the mouse heart in less than 10 minutes per slice.

Methods. A spiral cine DENSE sequence (2) was implemented on a 7T Clinscan system (Bruker/Siemens, Germany), and a cylindrical quadrature birdcage RF coil of diameter 30 mm and active length of 28 mm was used. A spiral *k*-space trajectory was chosen to minimize TE, and the data acquisition duration was limited to 3.1 ms to reduce blurring due to off-resonance effects. Low resolution field maps were acquired and image deblurring was also employed. Other data acquisition parameters included field of view = 25.6 mm, effective matrix = 128 x 128, slice thickness = 1 mm, TR = 6.9 ms, TE = 1 ms, number of averages = 4, number of spiral interleaves = 27, and displacement encoding frequency = 1.1 cycles/mm. Artifact-generating echoes were suppressed using 3-point phase cycling and through-plane dephasing with a frequency of 0.5 cycles/mm (3). The total scan time for a single 2D slice was 6 – 8 minutes, depending on heart rate, for images encoded for displacement in the two in-plane directions. For data analysis, segmentation of the heart was performed using a semi-automated technique (4) and displacement and strain were calculated using the phase unwrapping and motion tracking algorithms described in (5).

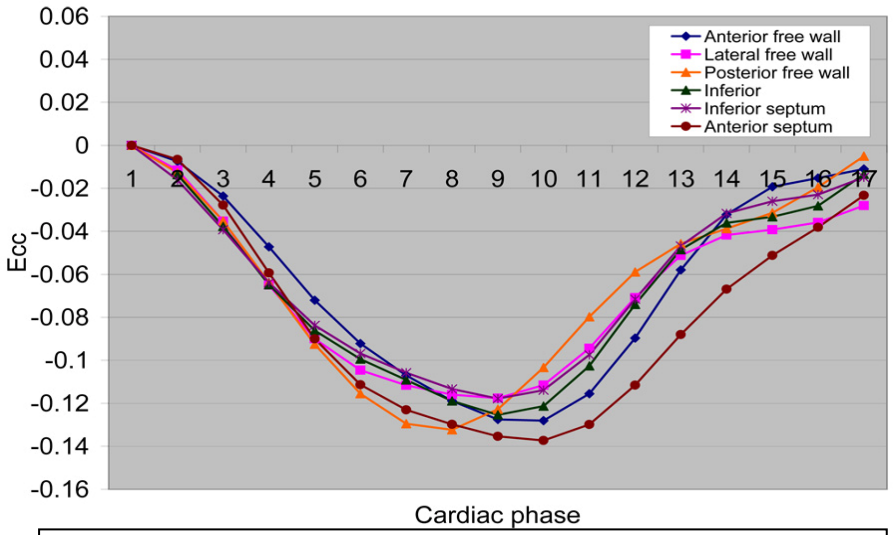

Fig. 1. Segmental strain-time curves from a short-axis slice of a normal mouse heart measured using 2D spiral cine DENSE implemented on a 7T scanner. Total data acquisition time was 6 minutes, and total image analysis time was 3 minutes.

Results. Using spiral cine DENSE at 7T and the RF coil specified above, the spatial and temporal resolution were 0.2 x 0.2 x 1 mm^3 and 6.9 ms, respectively. Under these conditions, magnitude-reconstructed images from the mid-ventricle of 4 mice had myocardial SNR of approximately 23, 18, and 12 at the beginning, middle, and end of the cardiac cycle, respectively, where the decrease in SNR with time is due to T1 decay of the stimulated echo. This SNR was more than adequate to achieve reliable cardiac segmentation, phase unwrapping of the DENSE phase-reconstructed images, and, subsequently, accurate estimation of myocardial displacement and strain. Example segmental strain-time curves from a normal mouse are shown in Fig. 1, where peak strains are consistent with previously reported data in mice (6). Example end-systolic displacement and strain maps (from multiphase data sets) are shown in Fig. 2 for a normal mouse and a mouse 7 days after induction of a myocardial infarction.

Discussion and conclusions. Using the methods described here, it is now practical to routinely use cine DENSE for the assessment of 2D regional contractile function in mouse models of heart disease, as the data acquisition time is now reasonable with respect to typical acquisition times for other imaging sequences in mice. Further significant reductions in scan time will likely be achieved using an RF coil with an active length less than 28 mm, as the longitudinal dimension of the mouse heart measures only approximately 8 mm.

Acknowledgements. Supported by NIBIB grant RO1 EB 001763.

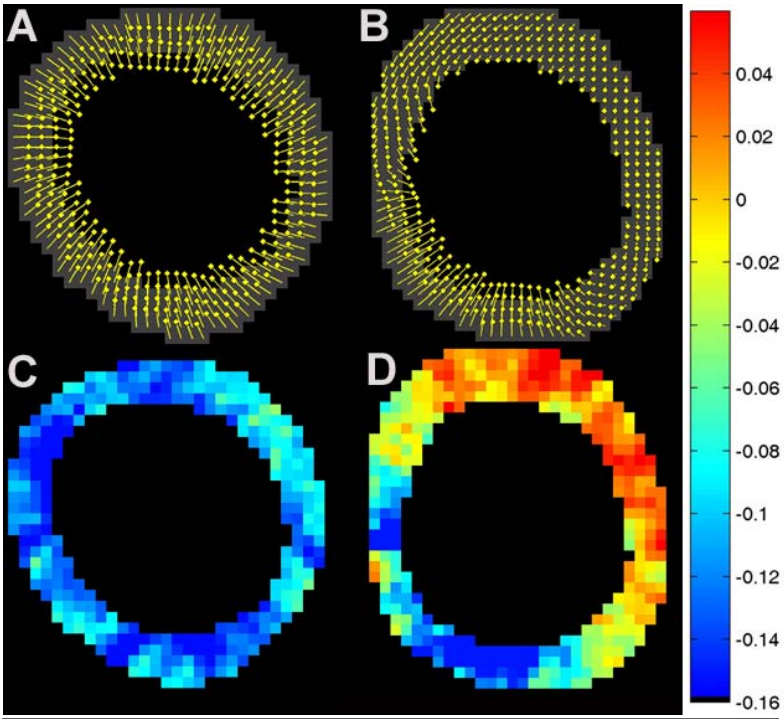

Fig. 2. End systolic short-axis cine DENSE displacement (A,B) and circumferential shortening (C,D) maps of the normal (A,C) and 7-day post-infarct (B,D) mouse heart. The region of infarction (11:00-5:00) has markedly reduced displacement (B) and shortening (yellow-orange).

1. Gilson et al. MRM 2004; 51:744-752. 2. Zhong et al.JCMR 9[2], 398-399. 2007. 3. Zhong et al. MRM 2006; 56:1126-1131.
4. Spottiswoode et al. Proc.Intl.Soc.Mag.Reson.Med. 794. 2006. 5. Spottiswoode et al. IEEE-TMI 2007;26[1]:15-30.
6. Gilson et al. AJP - Heart & Circulatory Physiology 2005; 288:H1491-H1497.