# SENSE-Accelerated Cardiac Strain MRI with DENSE

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**INTRODUCTION:**

Displacement Encoding with Stimulated Echoes (DENSE) has been developed for quantifying regional myocardial strain based on phase contrast images acquired during systole (1). Recent modifications to the original method (2,3) utilize RF phase cycling for suppressing the stimulated anti-echo and the unencoded FID signals. Despite the increased SNR due to the averaging employed, this type of RF cycling results in prolonged breath-holds, which are undesirable for patient scans.

We present the first phase-contrast DENSE myocardial strain imaging with Sensitivity Encoding (SENSE) (4). The application of SENSE-DENSE with an acceleration factor of two allows for imaging a slice within 14 heartbeats during a reasonable breath-hold.

**METHODS:**

All experiments were performed on a Excite 1.5T system (General Electric Waukesha, WI) with an eight element cardiac phased array (Nova, Boston, MA). Short axis 2D DENSE images were acquired with SENSE R=2 (and R=1 for reference) from a normal volunteer and a patient with coronary artery disease and evidence of myocardial infarction. Imaging parameters were: 2.9x2.9x8 $mm^3$ pixel size, ±62.5kHz bandwidth, 5ms TE, 1 heartbeat TR, 24 echotrain, meta-DENSE (5) readout, 4mm/π encoding strength, 2 averages (3). A noise-only scan and a low resolution full-FOV acquisition were performed for SENSE.

The noise in the strain maps was measured as follows. DENSE normally requires a reference phase image (R), an X-encoded (X) and a Y-encoded image i.e an R-X-Y set of images. To estimate the noise the following acquisitions were performed: R-R-R, X-X-X and Y-Y-Y. These acquisition sets should reflect no strain but rather the inherent noise of the strain measurements.

SENSE reconstruction was performed off-line with in-house software written in IDL (RSInc, Boulder, CO). Following SENSE unaliasing, strain was calculated as previously described (1,3). Results are reported as mean±s.d.

**RESULTS:**

Data from a patient with myocardial infarction are shown in Figure 1 with both R=1 and R=2. The eigenvectors and colored eigen values are at the top while circumferential shortening and radial thickening strain are at the bottom. A delayed enhancement image is also provided to visualize the infact. Average normal volunteer data for R-R-R, X-X-X and Y-Y-Y for R=1 yielded strain standard deviations for CS and RT of 4.9 and 6.4 respectively. The corresponding standard deviations with R=2 were 3.9 and 5.2 percent strain.

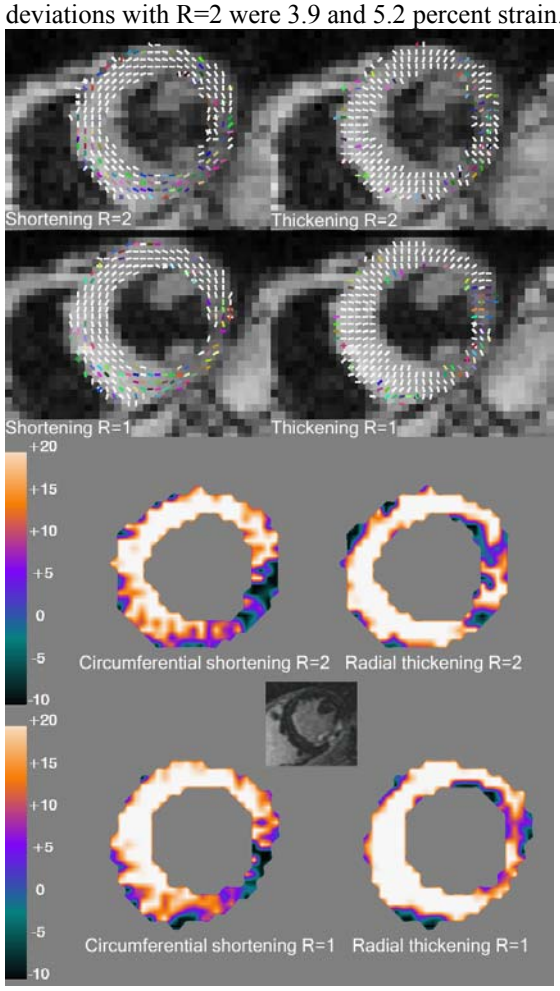


**Figure 1:** Shortening, thickening, circumferential shortening, radial thickening and Gd delayed enhancement images for a patient with myocardial infarction for SENSE-DENSE (R=1 and R=2) . Note that data quality is preserved with R=2.

**DISCUSSION:**

SENSE-DENSE acquires quality strain data at almost half the time (14 vs. 26 heartbeats). Physiological variation is limiting the strain measurements rather than the SENSE acceleration.

**REFERENCES:**

[1] Aletras et al., JMR 137 247-252 (1999)
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[3] Aletras et al., JMR 169, 246-249 (2004)
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