

## Accelerating global cardiac function assessment in mice using compressed sensing

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**Introduction:** Cine magnetic resonance imaging (cine-MRI) to assess global cardiac function in surgically or genetically modified mice is typically performed using single dedicated volume or surface coils, precluding the use of parallel imaging techniques to speed up the imaging process. Compressed sensing has been shown to accelerate the data acquisition process in MRI by sparse coding the signals in an appropriate transform domain, by incoherent sampling, followed by non-linear reconstruction (e.g. [1]). Thus, no specific hardware is required. Only few studies have reported on the application of this technique in cardiac MRI ([2,3]), but none in mouse hearts. The aim of this study was to investigate the feasibility of compressed sensing as an approach to accelerate cine-MRI in mice at 9.4T, and to quantify the impact of undersampling on global cardiac functional parameters.

**Methods:** Cine-MRI was performed on a horizontal 9.4T MR system comprising a VNMR5 DirectDrive console (Varian Inc., USA), a 1000 mT/m gradient system and a quadrature driven birdcage coil (id 33mm – Rapid Biomedical, Germany) optimized for cardiac application in mice. Eight weeks following surgical induction of myocardial infarction or sham operation (n=5 of each), mice were anesthetized and positioned prone in a dedicated animal cradle. Following scouting, tuning & matching, shimming and pulse calibration, seven to ten, fully-sampled contiguous slices in short axis view were acquired using a double-gated multi-frame gradient echo sequence (TE/TR=1.8/4.6ms, 256x256, FOV 25.6x25.6 mm,  $\alpha=15^\circ$ , NAE=2). These data sets were then undersampled (by factors 2, 2.5, 3 & 4, respectively) in offline post-processing by randomly selecting phase encoding steps from the fully acquired data set (the sampling scheme approximated a Gaussian distribution over the whole cycle of all acquired cine-frames – Fig. 1), and subjected to compressed sensing reconstruction. The resulting 50 data sets (i.e. 10 mice x 5 undersampling factors) were then Fourier transformed, randomized and exported into tiff format. The images were segmented (Amira 4.1, Visage Imaging, US) by a single operator, who was blinded to animal id and sampling scheme, and cardiac structural (i.e. left-ventricular end-diastolic (EDV) and end-systolic (ESV) volumes, LV-mass (LVM)) and functional parameters (stroke volume (SV) and ejection fraction (EF)) were calculated. A general linear model analysis for repeated measures (with Bonferroni correction) was used to compare fully and undersampled data sets. A p-value < 0.05 was considered statistically significant.

**Results:** Figure 2 shows mid-ventricular slices through a sham (top row) and an infarcted heart (bottom row), acquired in end-diastole and obtained with undersampling factors 1-4. Only minor degradation in image quality can be seen for all undersampling factors most pronounced for an undersampling factor of 4. This finding is also confirmed in the measured cardiac functional parameters, where no statistically significant differences were found for LV-mass, EDV, ESV or EF in any of the two groups (data not shown). In the sham group only, stroke volume (SV) was statistically significantly different between 4-fold undersampled and fully sampled data ( $31.0 \pm 3.1 \mu\text{l}$  vs  $37.1 \pm 4.1 \mu\text{l}$ ;  $p = 0.008$ ).

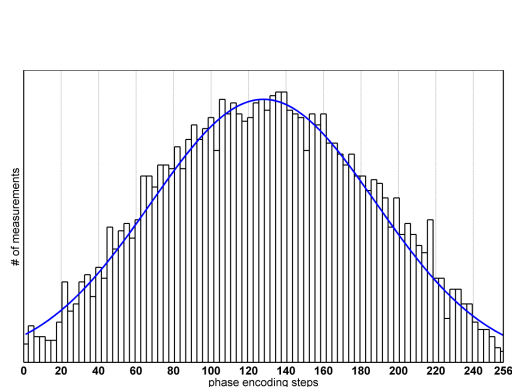


Figure 1: Random gauss sampling: histogram of all phase encoding steps over the whole cycle of all acquired cine-frames per slice.

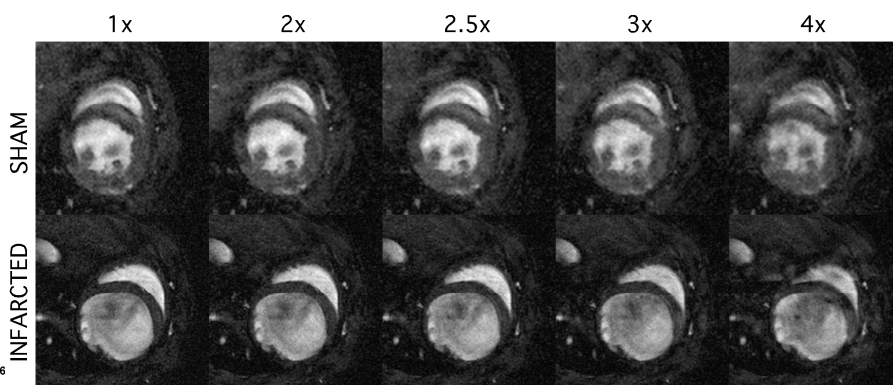


Figure 2: Mid-ventricular slices in end-diastole of a sham operated mouse (top row) and a mouse heart with chronic infarct (bottom row). Consistent image contrast and no major artefacts can be observed up to 4-fold acceleration.

**Discussion:** Our study demonstrates that an up to 3-fold undersampling is generally feasible without impairing accuracy of left-ventricular volumes and mass measurements. In order to minimize the impact of physiological variations during the MR experiments on the analysis of the different data sets, undersampling was performed in post-processing rather than during acquisition. However, work is in progress to implement the undersampling directly on the MR scanner to fully utilize the time saving potential of the technique.

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**References:** [1] Lustig M et al., Magn Reson Med. 2007 Dec;58(6):1182-95.; [2] Wech T et al, Rofo. 2010;182(8):676-81; [3] Jung H et al, Magn Reson Med. 2010; 63(1):68-78.