# Cardiac Multi-Contrast CINE: Real-Time Inversion-Recovery Balanced Steady-State Free Precession Imaging with Compressed-Sensing and Motion-Propagation

Aurelien F. Stalder[1], Peter Speier[1], Michael Zenge[1], Andreas Greiser[1], Christoph Tillmanns[2], and Michaela Schmidt[1]

[1]Siemens AG Healthcare Sector, Erlangen, Germany, [2]Diagnostikum Berlin, Berlin, Germany

**Introduction:** Myocardial infarction is typically diagnosed based on visual evaluation of wall motion abnormalities using CINE data with native bSSFP contrast and delayed-enhancement imaging (DE). Both, DE and CINE images are mostly acquired during breath-hold in a segmented fashion in order to achieve high temporal and spatial resolution which requires cooperative patients. DE is characterized as hyper enhancement after gadolinium injection and consists in an inversion recovery (IR) sequence where the inversion time (TI) is defined so that the healthy myocardium is nulled. When not using phase-sensitive IR, selecting the right TI is difficult and a TI-scout sequence is typically executed prior to DE. Suboptimal TI results in reduced contrast. We propose a new technique that allows the fast and robust imaging of CINE data with a retrospectively adjustable delayed-enhancement contrast in a short breath-hold of 4 seconds. The technique is based on highly accelerated IR 2D bSSFP real-time CINE using compressed sensing (CS) and k-t regularization. Subsequently, a registration and motion-propagation strategy is used to reconstruct CINE series for each of the acquired TI contrasts. Based on multi-TI CINE series, it is eventually possible to reconstruct CINE T1 maps (1).

**Materials and Methods:** Data were acquired in 7 volunteers and 6 patients on 1.5T and 3T MR scanners (Magnetom Aera & Skyra, Siemens AG Healthcare Sector, Erlangen, Germany) using a compressed-sensing sequence prototype. The bSSFP sequence used a CS technique with k-t regularization (2) to acquire real-time 2D cine images following an inversion pulse right after the first R-wave (similar to a TI-scout at high spatial and temporal resolution). Data were acquired over 4 cardiac cycles during breath-hold. The acquisition parameters were: reconstructed matrix size: 192 x 150, slice thickness: 8 mm, temporal resolution: 33 ms, TE / TR = 1.2 / 2.8 ms, net acceleration: 8.8. The acquisition produced IR real-time CINE images where inversion and trigger times are linked. While in the first cardiac cycle, the contrast changes between different TI are very strong, in the 4th cardiac cycle, the contrast is almost constant resulting in a "pseudo-CINE" sequence. Cross-registration between each image of the last cardiac cycle of the acquisition (pseudo CINE data) was performed and the deformation field corresponding to cardiac motion was extracted (Fig. 1). The fast elastic registration algorithm (3) used local cross-correlation for measuring image similarity, a multi-scale pyramidal approach for optimization and regularization based on low-pass filtering of the gradient images to derive a dense deformation field. The deformation field was then propagated to the cardiac cycle acquired directly after the inversion pulse to reconstruct CINE series for each of the TI contrasts (multi-TI CINE). Finally, a three-parameter recovery fit was performed on a voxel-by-voxel basis to calculate a CINE pseudo-T1 map. The CS reconstruction was performed inline but the multi-TI CINE series were calculated using a prototype implemented in Matlab and c++.

**Results:** The reconstruction of multi-TI CINE and pseudo-T1 map CINE series was successful in all subjects. An extract of the multi-TI CINE matrix for one patient is given in Fig. 2 with two different TI contrasts and a pseudo-T1 map represented at systole and diastole. The different TI contrasts as well as the pseudo-T1 map allow differentiating fat (yellow arrowhead) and infarct region (red arrows) that appear as one single region on the standard DE image with a longer TI (Fig. 3).

**Discussion:** Thanks to the use of a CS technique, it was possible to acquire real-time IR CINE data at sufficiently high spatial and temporal resolution to obtain diagnostic quality images in a 4-second breath-hold. Using a registration and motion-propagation strategy, it was possible to reconstruct multi-TI CINE series. The method allowed to 1) retrospectively select the desired TI contrast, 2) represent the DE images as CINE series and hence correlate abnormal contrasts with altered function 3) derive CINE pseudo-T1 maps. The pseudo-T1 maps obtained from the IR CINE images do not represent only T1 recovery and a correction might be needed to obtain accurate quantitative T1 values (4,5). Combining function and viability with retrospectively adjustable and dynamic TI contrasts and T1 mapping may allow easier image reading and enhanced diagnostic accuracy.

**References:** 1. Goldfarb JW et al. ISMRM; 2007. p. 2576. 2. Liu J et al. ISMRM; 2012. p. 178. 3. Guetter C et al. ISBI; 2011. pp. 590–593. 4. Schmitt P et al. Magn. Reson. Med. 2004;51:661–7. 5. Greiser A et al. ISMRM; 2012. p. 3851.
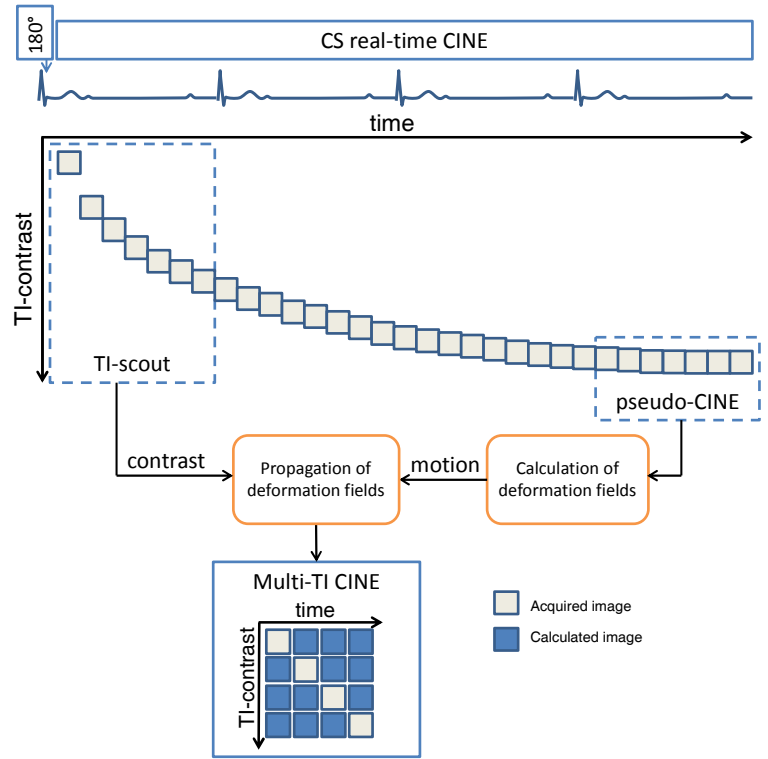
**Fig. 1** Acquisition and reconstruction strategy: after the CS real-time CINE acquisition, the motion from the 4th cardiac cycle is applied to the contrast from the first cardiac cycle to reconstruct a multi-TI CINE dataset.
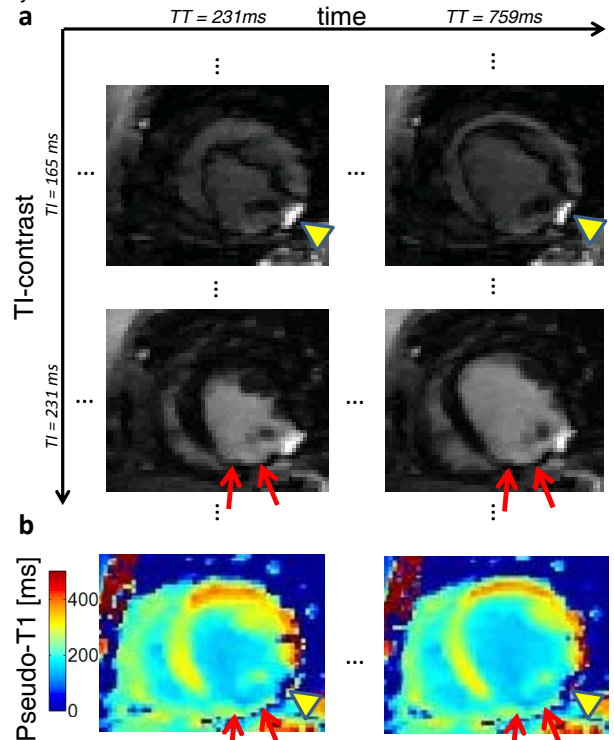


**Fig. 2** a: Extract of the multi-TI CINE matrix for a patient with myocardial infarct of the inferior ventricular wall. Two selected TI contrasts are displayed at systole (left) and diastole (right). b: corresponding maps of pseudo-T1
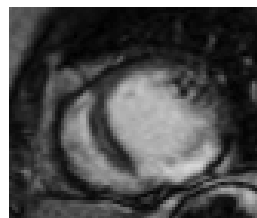


**Fig. 3** Reference DE image (TI=270 ms) for the patient of Fig. 2