High Resolution Myocardial T1 Mapping using MOLLI with Parallel Imaging and Compressed Sensing

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Targeted audience:

Researchers and clinicians in CV imaging and reconstruction.

Background:

Modified Look-Locker Imaging (MOLLI) is routinely used for T1 mapping of the left ventricle[1]. High resolution MOLLI requires fast imaging to remain free of artifacts due to cardiorespiratory motion. The combination of parallel imaging and compressed sensing (CS) has been used to accelerate cardiac cine and perfusion imaging[3-5] but not MOLLI. We developed an algorithm that combines parallel SENSE[2] and CS *kt*-Sparsity and Low Rank[3] (*kt*-SLR) and applied it to accelerate MOLLI to achieve high resolution (1.2×1.2 mm^2) T1 mapping using a standard breathhold clinical protocol (17 heartbeats).

Methods:

The *kt*-SENSE-SLR method combines parallel SENSE and CS *kt*-SLR. Sensitivity maps for SENSE were obtained using the center k-space lines. Multi-channel data were combined using SENSE, and singular value decomposition (SVD) was applied to the SENSE-merged images to exploit spatiotemporal correlations, thus utilizing information from all channels to increase sparsity. Iterative soft-thresholding was used to remove singular values below a threshold, as these mainly represent image noise[6]. T1 maps were estimated from the reconstructed images using a three-parameter fit.

Healthy volunteers (n=5) were imaged on a 1.5T scanner (Avanto, Siemens, Germany) using a 4-channel phased-array chest coil. An accelerated MOLLI sequence was implemented to fully sample the center of k-space and randomly sample high-spatial-frequency k-space lines with an overall acceleration rate of 4. High resolution (1.2×1.2 mm^2) and low resolution (1.8×1.8 mm^2) accelerated MOLLI images were acquired and reconstructed offline in MATLAB using the proposed *kt*-SENSE-SLR method. Standard MOLLI (with rate 1.7x parallel and partial Fourier acceleration, 2.2×1.8 mm^2) was also performed for comparison. For each scan, 11 inversion times were collected within one breath-hold. Other parameters are included in Table 1.

Results:

Figure 1 shows example images and T1 maps from standard MOLLI (A,D) and both high resolution (B,E) and low resolution (C,F) MOLLI accelerated with *kt*-SENSE-SLR. Images reconstructed using the proposed method resembled the fully-sampled images. Table 1 lists the average and standard deviation of T1 values for all volunteers from the myocardium and the blood for each method. The T1 values estimated with accelerated MOLLI showed good agreement with standard MOLLI and had lower standard deviations.

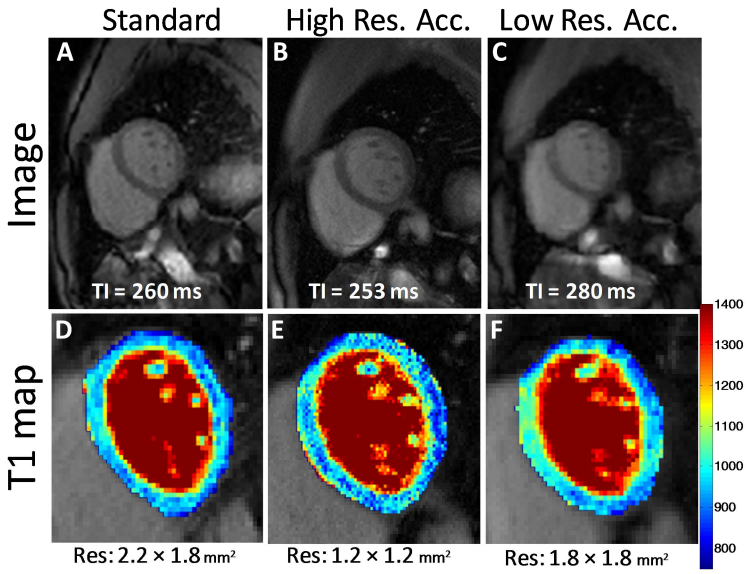

Figure 1. Images at one TI (A, B, C) and T1 maps (D, E, F) using standard MOLLI, accelerated high resolution CS-MOLLI and low resolution CS-MOLLI. Images from CS-MOLLI (B, C) were reconstructed using *kt*-SENSE-SLR. Undersampling artifacts were removed and detailed structures were well preserved. The corresponding T1 maps (E, F) demonstrate the accuracy of T1 estimation compared to standard MOLLI (D).

Table 1. Imaging parameters and T1 values from standard MOLLI and high resolution and low resolution accelerated CS-MOLLI with *kt*-SENSE-SLR. Average T1 values for myocardium and blood were calculated. Similar values were found among the three methods. T1 map noise was quantified as the T1 standard deviation over space. *kt*-SENSE-SLR had lower standard deviation values, indicating lower T1 map noise level.

	Standard	High Res. Acc.	Low Res. Acc.
Matrix Size	134×192	200×289	136×193
Resolution (mm)	2.2×1.8×8	1.2×1.2×8	1.8×1.8×8
TIs	11	11	11
Acq. Window (ms)	178±4	160±12	96±4
Myocardium Avg. T1 (ms)	953±70	979±42	974±48
Blood Avg. T1 (ms)	1322±77	1342±49	1310±52
T1 Std. deviation(ms)	106±18	89±13	91±24

Conclusions:

Excellent image quality and accurate T1 estimation were achieved using accelerated MOLLI with the combination of parallel and CS reconstruction techniques. High resolution T1 maps (1.2×1.2 mm^2) could be acquired within one breath-hold using this method. This technique can also be applied to reduce the acquisition window of MOLLI to reduce cardiac motion-induced artifacts.

References: [1] Messroghli et al. MRM 2004 52(1):141-6 [2] Pruessmann et al. MRM 1999 42:952-962 [3] Lingala et al. IEEE 2011 30:1042-54 [4] Tsao et al. MRM 2003 50(5):1031-42 [5] Pedersen et al. MRM 2009 62(3):706-16 [6] Combettes et al. Multiscale Model Simul 2005 4:1168-1200

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