CMR Acceleration using iterative k-t-sparse SENSE reconstruction

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Background: Cardiovascular MRI is an increasingly used tool for diagnosis and treatment planning in patients with cardiovascular disease. However, due to the dynamic nature of the cardiopulmonary system, many cardiovascular applications rely on a combination breath-holding, ECG- and respiratory-gating, and/or motion correction to reduce respiratory artifacts and improve image quality. In an effort to reduce patient breath-hold times and shorten clinical MRI exams, we have applied iterative segmented k-t-sparse Cartesian SENSE balanced steady state free precession (SSFP) cinegraphic imaging in patients undergoing clinical CMR. The technique uses iterative k-t SENSE (1) with L1 regularization along one spatial dimension and the temporal dimension to reconstruct temporally undersampled k-space data (2) and reduce scan time. In this study, we have quantitatively and qualitatively compared the clinical implementation of the accelerated MR acquisitions with standard CMR cine acquisitions.

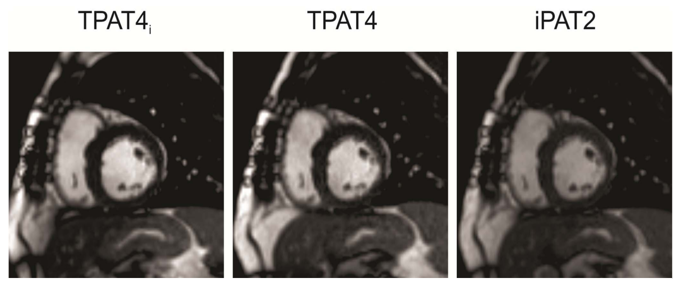

Figure 1: A comparison of mid-short axis slices of a patient undergoing CMR with the two accelerated acquisitions ($TPAT4_i$) and (TPAT4) as well as the standard segmented SSFP (iPAT2).

Methods: Twenty patients (age: 54.8 ± 14 years, M:F = 15:5) undergoing non-emergent CMR assessment for myocardial pathology were consecutively recruited as a part of this IRB approved study. CMR was performed at 1.5T (MAGNETOM Aera, Siemens Healthcare, Erlangen, Germany) and included acquisition of standard segmented SSFP (iPAT2) (GRAPPA accel factor 2, TR 40msec, 2.1x2.1x10 mm^3) cine and two accelerated segmented SSFP acquisitions (TPAT accel factor 4, TR 37.7msec, 2.1x2.1x6 mm^3), one with an investigational prototype inline iterative k-t-sparse SENSE reconstruction with L1 regularization along one spatial and temporal dimension ($TPAT4_i$) (1)and the other with conventional SENSE reconstruction (TPAT4). Each technique was used to acquire a short axis (SA) series in identical slice positions (Figure 1), with SA coverage of the entire left ventricle (LV) with 10 mm interslice gaps. Individual slice scan times were recorded. Quantitative LV functional analysis was performed. A reviewer blinded to acquisition type scored images for overall image quality, noise, and artifacts using a 5-point Likert scale. Qualitative findings were compared between scan types using Kruskall-Wallis test and quantitative findings were compared using Student's t-test. A p-value < 0.05 was considered significant.

		$TPAT4_i$		TPAT4		iPAT2	
		Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
Image Quality	Base	$4.15^{\&}$	0.81	$3.50^{\&}$	1.51	$4.80^{*,\#}$	0.41
	Mid	$4.75^{\#,\&}$	0.44	$4.25^{\&,*}$	0.77	$4.80^{*,\#}$	0.52
	Apex	4.90	0.31	3.94	1.98	4.80	0.41
Noise	Base	$4.40^{\&}$	0.68	$4.00^{\&}$	0.68	$4.80^{*,\#}$	0.41
	Mid	$4.60^{\#,\&}$	0.60	$4.13^{\&,*}$	0.72	$5.00^{*,\#}$	0.00
	Apex	4.85	0.37	4.77	0.60	4.95	0.22
Artifact	Base	$4.25^{\&}$	0.72	$4.57^{\&}$	0.51	$4.85^{*,\#}$	0.37
	Mid	4.70	0.57	4.81	0.54	4.80	0.41
	Apex	4.95	0.22	4.92	0.28	4.75	0.44

Table 1: Comparison of qualitative assessment between sequences. * - sig. difference with $TPAT4_i$, # - sig. difference with TPAT4, & - sig. difference with iPAT2

Results: There was no difference in LV ejection fraction between iPAT2 and $TPAT4_i$ (p = 0.38) or TPAT4 (p = 0.38) in this group of patients. As anticipated, $TPAT4_i$ (3.29 ± 0.6 sec) and TPAT4 (3.0 ± 0.6 sec) acquisitions were significantly shorter relative to iPAT2 (8.4 ± 1.7 sec, p < 0.001 for both). Qualitative review showed significantly higher image quality, lower noise, and consistently less artifact in the iPAT2 acquisitions than either accelerated technique (Table 1). Of note, regional variability in image quality characteristics was present in both accelerated techniques, with qualitative scores improving as slices progressed from base to apex. (Figure 2)

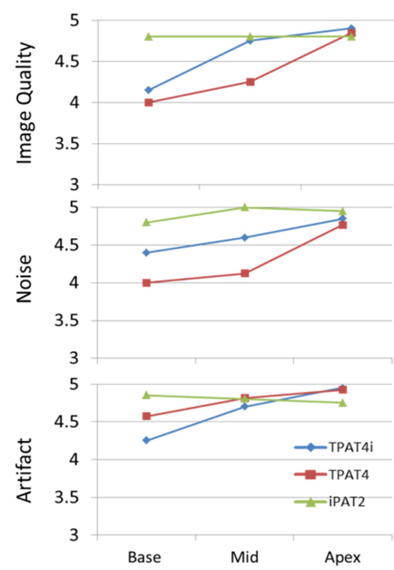

Figure 2: Visual Comparison of qualitative review results demonstrating the trend for improved qualitative assessment with progression from base to apex for the acceleration techniques.

Conclusions: Iterative k-t-sparse SENSE techniques can be successfully applied in CMR to reduce scan times by >50% while maintaining diagnostic image quality and quantitative accuracy in LV systolic function assessment. This finding is likely secondary to increased wrap artifact at the base and is in keeping with the known sensitivity of the SENSE technique to FOV settings. Further work to reduce reconstruction times and improve clinical workflow integration is ongoing.

References: 1. Liu et al. ISMRM 20th Annual Meeting. (2012). **2.** Kannengiesser et al. ISMRM 8th Annual Meeting. (2000).

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