Comparison of K-t SPIRiT and K-t GRAPPA for Accelerating Cardiac DCE and CINE MRI

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Target Audience: The target audience for this document includes those who show interest in acceleration of dynamic cardiac MRI

Purpose: Dynamic cardiac magnetic resonance imaging requires high spatiotemporal resolution. Thus, imaging acceleration is needed. A popular acceleration method is to under-sample the k-space during acquisition and interpolate the missing k-space data in k-t domain [1]. K-t GRAPPA method has been proven to be efficient for under-sampled cardiac dynamic contrast enhanced (DCE) and CINE image reconstruction [1, 2]. Recently, k-t SPIRiT has been proposed to accelerate cardiac dynamic phase contrast imaging [3]. However, k-t SPIRiT hasn't been validated in cardiac DCE and CINE. This study sought to test the performance of k-t SPIRiT with k-t GRAPPA as a comparison on cardiac DCE and CINE MRI.

Methods:

DCE data: A set of 6-channel myocardial perfusion data was acquired on a Philips 1.5 T system (Philips, Best, the Netherlands) with a saturation recovery, spoiled gradient echo sequence (TR/TE=2.6/1.4, FA=15°, FOV 256×256mm^2, matrix size: 144×240, slice thickness 10mm).

CINE data: A set of 32 channel cardiac CINE of a healthy volunteer was acquired on the same Philips scanner using balanced TFE sequence (TR/TE=3.4/1.72, FA=60°, FOV 256×256mm^2, matrix size: 312×158, slice thickness 8mm, 15 cardiac phases) with electrocardiography gating (ECG) in single 23s-long breath-holds.

Image reconstruction: The fully sampled DCE and CINE datasets were retrospectively under-sampled using the optimized trajectory described in [4]. Four acceleration factors were used: 4, 6, 8, and 10 to test their performance, with an ACS region of 15 phase encoding lines. Then the under-sampled k-spaces were reconstructed by k-t SPIRiT and k-t GRAPPA respectively. In k-t SPIRiT, a 7×3 kernel was used for DCE, and a 5×5 kernel for CINE. The reconstruction was solved by CG algorithm with Tikhonov regularization [5]. All codes were implemented in Matlab and processed on a computer with Intel(R) Core(TM)2 Duo CPU L9600 @ 2.13GHz.

Data analysis: ROIs of the whole heart were drawn on both datasets (Fig.1 and Fig.2: red contour). Additionally, ROIs were delineated in right ventricle (Fig.1: blue contour) and myocardium (Fig.1: yellow contour) on DCE images. The intensity evolutions of the blood in right ventricle and myocardium were compared. The difference between the reconstructed images and fully sampled reference images of these ROIs were compared among k-t SPIRiT and k-t GRAPPA using the root mean square error (RMSE). The reconstruction time of both methods were also compared.

Results: In DCE, the reconstructed images by k-t SPIRiT show similar quality with those by k-t GRAPPA (Fig.1a). The evaluation curves of blood and myocardium generated by both methods are very close to original curves at acceleration factor 6 (Fig. 1b). The RMSE of k-t GRAPPA is lower than k-t SPIRiT for each reduction factor, especially for myocardium (Table1). Same as DCE, k-t SPIRiT has similar performance with k-t GRAPPA on CINE dataset (Fig. 2); K-t GRAPPA also has lower RMSEs than k-t SPIRiT at all tested acceleration factors (Table 2). As for the reconstruction time, k-t SPIRiT was over 4 times than k-t GRAPPA (Table 3).

Discussion and Conclusion: In this study, we validated k-t SPIRiT on cardiac DCE and CINE applications with good and similar performance compared with k-t GRAPPA. Although the results are similar, k-t SPIRiT do have a slightly, but consistently, larger reconstruction error in cardiac region and much higher computational cost than k-t GRAPPA. K-t SPIRiT iterations may be the major cause of slow reconstruction and noise amplification. Thus, k-t GRAPPA is preferred for accelerating cardiac DCE and CINE MRI with interleaved acquisition due to lower reconstruction error and lower computational cost. K-t SPIRiT could be used where k-t GRAPPA is limited, such as randomly sampled k-space.

Reference: [1] Huang, MRM, 2005;54(5):1172-1184
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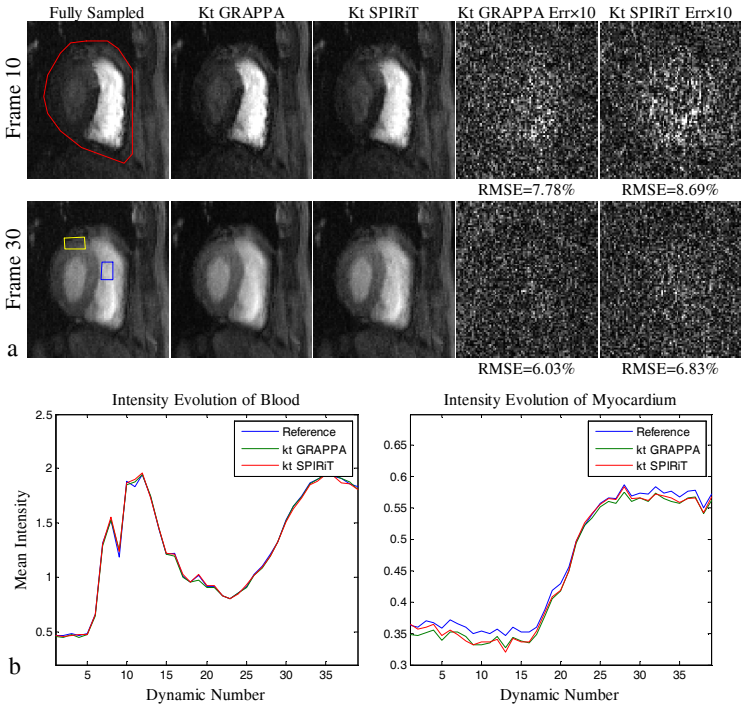

Fig.1 Reconstructed images (a) and their intensity Evolutions (b) of k-t GRAPPA and k-t SPIRiT on cardiac DCE data at reduction factor of 6.

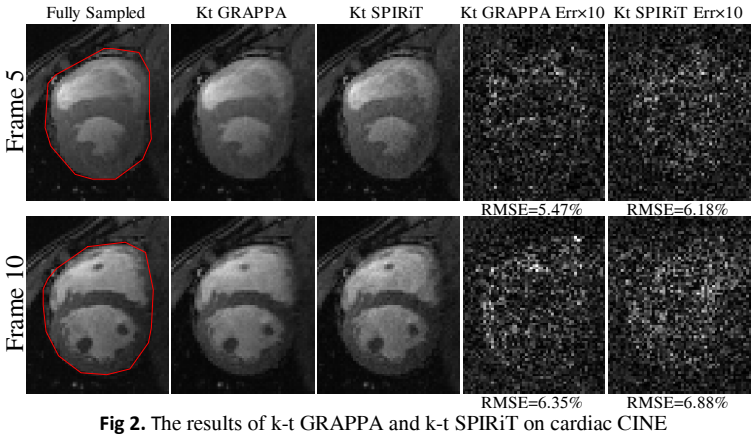

Fig 2. The results of k-t GRAPPA and k-t SPIRiT on cardiac CINE when reduction factor is 6.

Table 1 Averaged RMSEs for kt GAPPA (GP) and kt SPIRiT (SP) on DCE for all frames

R	Heart (%)		Blood (%)		Myocardium (%)	
	K-t GP	K-t SP	K-t GP	K-t SP	K-t GP	K-t SP
4	7.1	9.0	6.3	7.4	11.8	14.1
6	8.1	9.4	7.6	8.8	13.0	14.6
8	8.9	10.3	8.2	9.1	14.0	15.7
10	9.8	10.8	9.1	9.5	15.0	16.0

Table 2 averaged RMSEs of CINE

R	Heart (%)	
	K-t GP	K-t SP
4	5.5	6.4
6	6.8	7.3
8	7.8	8.3
10	9.4	9.9

Table 3 Reconstruction Time at factor 6

	K-t GP	K-t SP
DCE	23s	159s
CINE	234s	1111s