Highly Accelerated Cardiac Cine Imaging Using a Combination of k-t Group Sparse and SPIRiT

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Target audience: Radiologists and MR scientists working on cardiac imaging and/or fast imaging methods.

Purpose: Cardiac cine imaging has been widely used to characterize the cardiac functions in many diseases. It requires both high spatial and temporal resolution, which are difficult to be fulfilled at the same time. Thus, acceleration methods are necessary. SPIRiT is an iterative self-consistent parallel imaging reconstruction method, which utilizes kspace correlations to accelerate imaging speed [1]. However, the diagnostic information might be damaged due to the g-factor when acceleration factor is high. Recently, k-t group sparse (k-t GS) [2] has been proposed to utilize similarity in k-t space for imaging acceleration. To further achieve higher acceleration factor, k-t group sparse SENSE (k-t GSS) [3] has been proposed for dynamic imaging by combining k-t acceleration and parallel imaging. Excellent image quality has been demonstrated with high acceleration factors. However, it's hard to achieve perfect sensitivity maps consistently during dynamic acquisition. In this study, the k-t GS-SPIRiT, a combination of k-t group sparse and kspace-based SPIRiT, was proposed and tested on accelerated cardiac cine imaging.

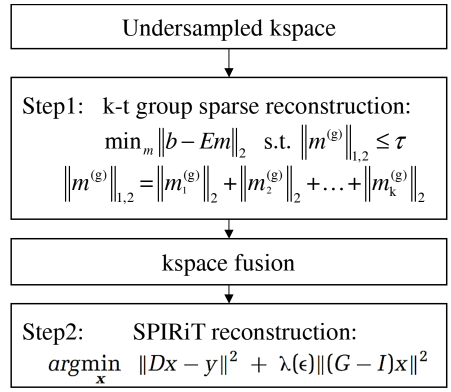

Fig.1 *Flowchart of k-t GS-SPIRiT. The algorithms of each step are listed in the blocks.*

Methods: A sequential combination scheme is proposed (Fig.1): (1) k-t group sparse is performed to generate the initial reconstruction. (2) SPIRiT uses the result of k-t group sparse to train kernel and as initialization for the iteration. To test the feasibility of this method, a set of cardiac data was acquired on a Philips 1.5 T system (Philips, Best, the Netherlands) with a 32-channel cardiac coil (Invivo Corp., Gainesville, FL) and with electrocardiography gating (ECG). A healthy volunteer was scanned using balanced TFE sequence in a single 23s-long breath-holds. The acquisition parameters were: FOV 320×320mm^2, matrix size 312×158, number of phases 15, TR 3.4ms, TE 1.72ms, flip angle 60°, slice thickness 8 mm, and number of averages 1. Fully-sampled k-space data was retrospectively down-sampled using a variable density random sampling trajectory. The proposed k-t GS-SPIRiT was performed to reconstruct the images, with SPIRiT and k-t GS as comparisons. High reduction factors of 8 and 10 were tested. The root mean square error (RMSE) of the heart region compared with fully sampled reference image was used for evaluating the reconstruction error. ROIs of heart were drawn on each frame of the cine imaging, Fig.2e shows an example ROI (red contour).

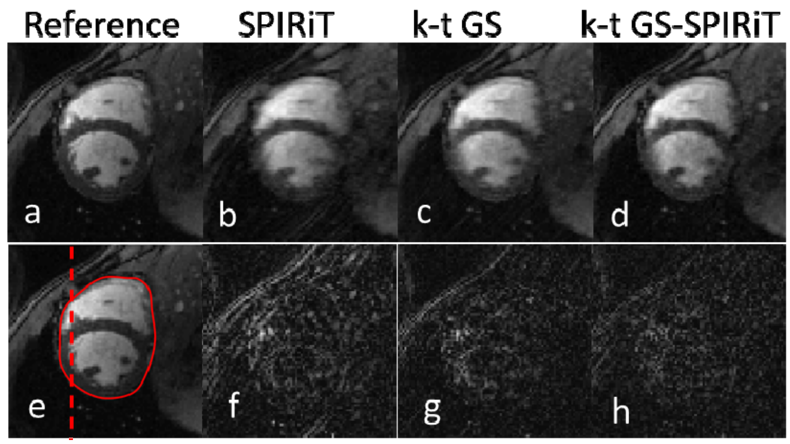

Fig.2 *(a): Fully-sampled cardiac cine images for the 1st frame. (b-d): Reconstructed image using SPIRiT, k-t GS and k-t GS-SPIRiT at a reduction factor of 8. (e): The region of interest (ROI) selected for the evaluation of Root-Mean-Square Error (RMSE); (f-h): Corresponding error maps between reconstructed images and fully-sampled images.*

Results: Fig.2 and Fig 3 show that k-t GS-SPIRiT resulted in the best image quality with the lowest error, compared with other methods. It eliminates most of the artifacts with less blurring than other methods (red arrows in Fig 3). Table 1 demonstrates that the proposed combined method has better reconstruction accuracy than using SPIRiT or k-t GS alone, especially when the acceleration factor is high.

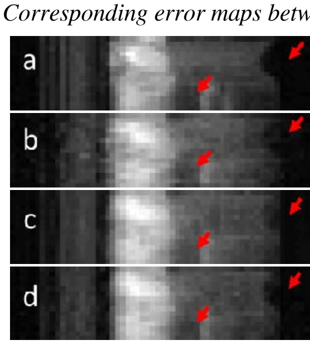

Table 1 Mean Root-Mean-Square Error (RMSE) of all dynamic frames for SPIRiT, k-t GS and k-t GS-SPIRiT

Reduction Factor	Reconstruction algorithm	RMSE for the whole heart
8	k-t GS-SPIRiT	7.95%
	k-t GS	8.32%
	SPIRiT	10.09%
10	k-t GS-SPIRiT	9.65%
	k-t GS	10.16%
	SPIRiT	11.80%

Fig.3 *Temporal evolution for a particular frequency-encoding line passing through the red dashed line in Fig.2e. (a): Fully-sampled cardiac cine images. (b-d): Reconstructed image using SPIRiT (b), k-t GS(c) and k-t GS-SPIRiT (d) at a reduction factor of 10. The arrows point to the different image quality.*

Discussion: The proposed k-t GS-SPIRiT sequentially combines k-t GS and SPIRiT. k-t GS provided the signal for accurate kernel calibration, and the excellent initialization. SPIRiT used the correlation among channels and further reduced the artifacts due to temporal blurring by k-t GS. Thus, this combination is able to overcome the loss of detailed structure in k-t group sparse and the SNR decrease in SPIRiT.

Conclusion: We proposed a k-t GS-SPIRiT method to combine k-t group sparse and parallel imaging, which can result in images better than each individual method in cardiac cine image.

References:

[1] Lustig et al. *Magn Res Med*, 2010, 64: 457-471; [2] Usman et al. *Magn Res Med*, 2011, 66:1163-1176; [3] Usman et al. *Proc. Intl. Soc. Mag. Reson. Med*. 2011, 19: 67.