

Comparison of Reconstruction Methods for Accelerated Cardiac MR Stress Perfusion with Radial Sampling After Physiological Exercise

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Target Audience

Scientists and clinicians who are interested in myocardial perfusion

Purpose/Introduction

Cardiac MR perfusion allows the assessment of the functional significance of coronary stenosis and can be performed at rest or during stress using either pharmacologic stress or physiologic stress. Physiologic stress provides unique information regarding the patient's exercise capacity, hemodynamic response to exercise, and the extent of physical activity that can reproduce the patient's symptoms. However, physiological stress CMR perfusion is challenging due to rapid heart rates as well as the inability of patients to perform breath-holding. Spatial-temporal accelerated methods such as k-t SENSE, HYPR, compressed sensing using temporal sparsity are used extensively to accelerate CMR perfusion data acquisition. However, application of these methods in physiological CMR perfusion is very limited due to rapid and varying respiratory motion immediately post-exercise. Radial imaging has been recently explored in pharmacological and rest stress perfusion but its performance in physiological stress perfusion and optimal reconstruction strategy without exploring temporal sparsity/correlation has not been investigated. In this study, we sought to compare the performance of four non-linear reconstruction methods for accelerated physiological stress CMR perfusion with radial sampling.

Materials and Methods

All images were acquired on a 1.5T Philips Achieva (Philips Healthcare, Best, The Netherlands) with a 32-channel cardiac phased array coil. Eight healthy adult subjects (25.7±7.3 y, 2 men) underwent rest and physical stress CMR perfusion. The two scans were separated by 30 minutes and acquired in a random order for each subject.

Exercise Protocol: Exercise was performed using an MR-compatible supine bicycle ergometer (Lode B.V, Groningen, The Netherlands) mounted on the MR-table. After initial slice localization and coil sensitivity map calculation, the MR-table was moved out of the magnet bore while the subject remained supine. An exercise protocol (initial ergometer resistance=25 Watts, 25 Watts increments every 2 minutes) was performed to reach a target heart rate of ~140-150 beats per minute (bpm). Immediately after exercise, the MR-table was repositioned into the magnet bore for imaging.

Imaging protocol: After contrast administration (0.05 mmol/kg of Gadopentetate Dimeglumine), radial CMR perfusion imaging was acquired using a linear-radial SSFP sequence with a 90° saturation preparation pulse. The temporal resolution was fixed to ~120 ms for rest perfusion (43 radial spokes) and ~70 ms for exercise stress perfusion (22 radial spokes). Three slices were acquired per heart beat in the short axis orientation using the following parameters: TR/TE/α=2.78/1.39/50°, FOV=300×300mm², resolution=2.2×2.2×10mm³, and 88 dynamics per slice.

Image Reconstruction: Four non-linear reconstruction methods were compared: 1) gridding reconstruction using the NUFFT package¹, 2) Conjugate Gradient (CG) SENSE², 3) compressed sensing with first-order total variation constraint (TV)³, 4) Regularized non-linear inversion with joint estimation of coil sensitivity maps (NLINV)⁴.

Data Analysis: Two experienced cardiologists, blinded to subject information and acquisition scheme, independently performed a subjective qualitative assessment of image quality using a 4-point scale (1-excellent; 4-poor). The subjective scores were averaged from the two readers and presented as mean ± standard deviation and were compared between methods using Wilcoxon's signed rank test.

Results

Figures 1 and 2 show four reconstructions of radial perfusion data acquired during rest and stress perfusion, respectively. Perfusion images acquired immediately following physiological stress perfusion had inferior image quality compared with images acquired at rest perfusion. Gridding images show streaking artifacts and higher noise level for post-stress perfusion, whereas the TV reconstruction provides patchy looking images. Table 1 shows the subjective image scores as assessed by the two blinded readers. For rest and stress perfusion, CG-SENSE and NLINV reconstruction methods show statistical superior results than gridding and TV.

	GRIDDING	CG-SENSE	NLINV	TV
Rest	1.88 ± 0.72 (2)	1.50 ± 0.63 (1)	1.38 ± 0.62 (1)	2.00 ± 0.73 (2)
Stress	2.83 ± 0.83 (3)	2.25 ± 0.62 (2)	2.25 ± 0.87 (2)	3.42 ± 0.51 (3)

Table1. Overall image quality obtained for rest and exercise stress perfusion. Mean ± standard deviation (median) scores are reported for each reconstruction method.

Conclusions

We demonstrate the feasibility of accelerated CMR perfusion using radial sampling after physiologic exercise using an MR-compatible supine bicycle ergometer. Conjugate gradient SENSE and non-linear inversion resulted in better image quality than standard gridding or TV reconstruction.

Acknowledgements

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References

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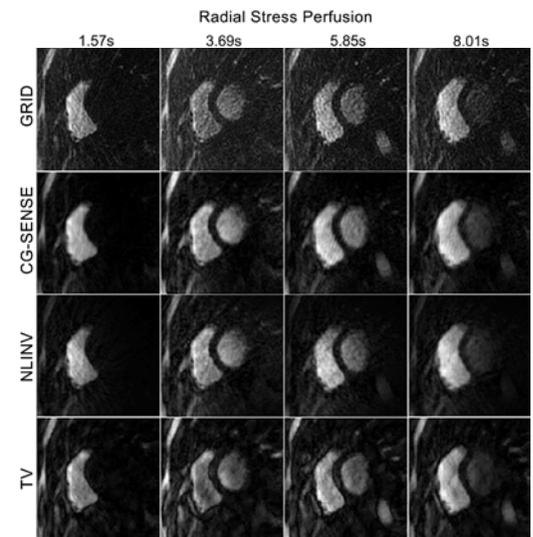


Figure 2. Comparison of the four reconstruction methods in a radial stress perfusion dataset. Improved image quality was obtained with CG-SENSE and NLINV.

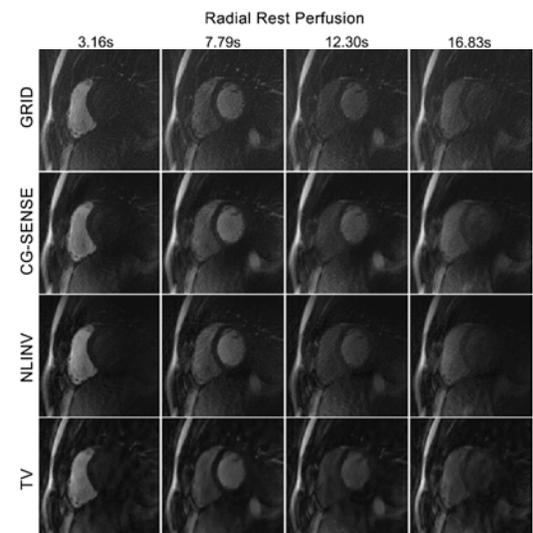


Figure 1. Comparison of the four reconstruction methods in a rest perfusion dataset. CG-SENSE and NLINV yield similar image quality and outperformed the other two reconstruction methods.