COMPARISON OF RECONSTRUCTION METHODS FOR ACCELERATED CARDIAC MR STRESS PERFUSION AFTER PHYSICAL STRESS WITH SUPINE ERGOMETER

Christophe Schülke[1,2], Sébastien Roujol[1], Murilo Foppa[1], Ernest V Gervino[1], Kraig V Kissinger[1], Beth Goddu[1], Sophie Berg[1], Sebastian Kozerke[2], Warren J Manning[1,3], and Reza Nezafat[1]

[1]MEDECINE, BIDMC / HARVARD MEDICAL SCHOOL, BOSTON, MA, UNITED STATES, [2]INSTITUTE FOR BIOMEDICAL ENGINEERING, UNIVERSITY AND ETH ZURICH, ZURICH, SWITZERLAND, [3]RADIOLOGY, BIDMC / HARVARD MEDICAL SCHOOL, BOSTON, MA, UNITED STATES

INTRODUCTION:

Physiologic stress provides unique information regarding a patient's exercise capacity and hemodynamic response to exercise. However, constraints to physical exercise within the magnet limit physiologic cardiac MR (CMR) stress testing. To address this issue, we employed an MR-compatible supine ergometer (Lode B.V., Groningen, NL) mounted on the scanner table (Figure 1) with exercise performed immediately outside the magnet bore. To allow CMR perfusion with an elevated heart rate, image acquisition needs to be shortened. In our experience, acceleration methods such as SENSE [1] or k-t SENSE [2] result in image artifacts due to corrupted coil sensitivity maps generated by the patient motion during exercise. k-t approaches also result in imaging artifacts due to the significant respiratory motion encountered post exercise. The aim of this study was to investigate the feasibility of CMR perfusion immediately following physical stress using compressed sensing (CS) [3] with a dynamic by dynamic reconstruction and to perform a comparison with SENSE [1] and with a reconstruction based on regularized nonlinear inversion (RNI) [4].

Figure 1. MR compatible supine exercise imaging apparatus mounted on the MR scanner at 1.5T.

METHODS:

Seven healthy adult subjects (24±3 years, 2 M) underwent a CMR perfusion exam. All images were acquired on a 1.5T Philips Achieva using a 32-channel phased array coil (Philips Healthcare, Best, The Netherlands). After an initial localization and coil map measurements, the table was moved out of the magnet bore while the subject remained supine. An exercise protocol was performed with initial ergometer resistance set to 25-50W. The resistance was then increased every two minutes by 25W increments to reach a target heart rate of ~140 bpm. ECG rhythm and blood pressure were monitored throughout the exercise protocol. After completion of exercise, the table was then rapidly repositioned in the magnet bore followed by an injection of 0.05mmol/kg of Gd-DTPA and the CMR perfusion sequence. A saturation-recovery GRE sequence (TR/TE/α=2.6/1.3ms/20°, resolution=2.4×2.4×10 mm^3, 90 dynamics) was employed with an acceleration factor of 4-5 to acquire 3 slices/heart beat. We implemented a prospective CS acquisition including full sampling of the k-space center and random undersampling of the outer k-space. The same exercise protocol was repeated 30 minutes later using SENSE for the CMR perfusion acquisition using a uniform undersampling pattern and the clinically available SENSE reconstruction. The ordering of two protocols was randomly changed between different subjects. Randomly undersampled data were reconstructed off-line in a dynamic-by-dynamic fashion using two different algorithms: CS with total variation (TV) regularization based on the fast alternating minimization approach [5] and a RNI based reconstruction jointly estimating coil sensitivities and image content [4]. Each algorithm was first pre-calibrated on 3 subjects and the same pre-optimized parameters were employed for all subjects. Image quality was evaluated by a blinded CMR practitioner using a 1 (poor) to 4 (excellent) scale. Image score obtained for the three reconstruction methods were compared and analyzed using a Wilcoxon signed-rank test.

RESULTS:

All imaging was successfully performed and all subjects were able to achieve the targeted heart rate. Figure 2 shows reconstructed images using the three reconstruction methods. Noise amplification and artifacts were present in SENSE reconstruction, while CS with TV and the RNI reconstruction provided images with substantial improvement (Figure 2). CS with TV achieved a better reconstruction than the RNI reconstruction in term of sharpness and image quality.

There was a trend for RNI reconstruction to be scored superior to SENSE (2.4±0.8 vs. 1.4±0.5, p=0.06). No statistical difference was observed between CS with TV and the RNI reconstruction (2.6±0.5 vs. 2.4±0.8, p=1). However, images reconstructed using CS with TV were scored significantly higher than SENSE (2.6±0.5 vs. 1.4±0.5 p<0.05).

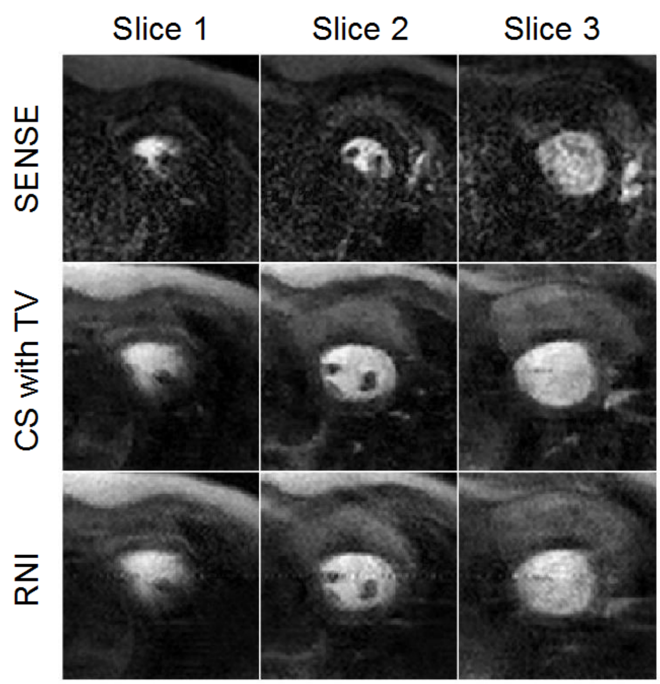

Figure 2. Three slices from a CMR perfusion with an acceleration rate of 4 reconstructed using SENSE (upper row), Compressed Sensing (CS) with total variation (TV) regularization (middle row) and the regularized nonlinear inversion (RNI) reconstruction (lower row). The CS images have superior signal with minimal artifacts.

CONCLUSIONS:

Accelerated 2D CMR stress perfusion after physical stress allows assessment of myocardial perfusion. The CS reconstruction with TV regularization offers improved image quality when compared with SENSE reconstruction in a head-to-head comparison in subjects undergoing CMR perfusion post physical exercise.

References:

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