

Radial versus Cartesian Sampling for Physiological Stress CMR Perfusion: A Head-to-Head Comparison

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Target Audience

Scientists and clinicians who are interested in myocardial perfusion.

Purpose/Introduction

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, this technique is challenging due to the patient inability to breath-hold after exercise and the elevated heart rate. Perfusion imaging is commonly performed using Cartesian sampling of k-space. Non-Cartesian sampling schemes, such as radial or spiral, have recently received attention for pharmacological stress CMR perfusion due to their data acquisition efficiency and robustness to motion. However their performance in physiological stress perfusion has not yet been fully investigated. In this study, we sought to perform a head-to-head comparison between CMR perfusion data acquired using radial and Cartesian sampling strategies.

Materials and Methods

All images were acquired on a 1.5T Philips Achieva (Philips Healthcare, Best, The Netherlands) using a 32-channel cardiac phased array coil.

Study Design: Eight healthy adult subjects (25 ± 7 y; 2M) underwent two physiologic stress CMR perfusion studies on two separate sessions at least 7 days apart. Figure 1 shows the protocol of the proposed study. In each session, subjects were scanned using stress and rest protocols as described below. All images were acquired using Cartesian sampling in one session, and using radial sampling in the other session. The order of rest and stress perfusion scans was randomized in session one, but was kept constant for the second session. A delay of 30-40 min was added between contrast agent injections to allow for contrast agent washout.

Exercise Protocol: Exercise was performed using an MR compatible supine bicycle ergometer (Lode B.V, Groningen, The Netherlands) mounted on the MR-table. After acquisition of localizer (scout) images and coil sensitivity maps, the MR-table was moved out of the magnet bore while the subject remained supine. Subsequently, an exercise protocol with initial ergometer resistance of 25 Watts (step=+25 Watts/2 minutes) was performed to reach a target heart rate of ~140-150 beats per minute (bpm). After exercise, the MR-table was immediately repositioned into the magnet bore for imaging.

Imaging protocol: After contrast administration (0.05 mmol/kg of Gadopentetate Dimeglumine), CMR perfusion imaging was acquired using a saturation recovery SSFP sequence. The temporal resolution was fixed to ~120 ms for rest perfusion (43 radial spokes (radial) / SENSE rate=2.75 (Cartesian)) and ~70 ms for exercise stress perfusion (22 radial spokes (radial) / SENSE rate=3.5 (Cartesian)). Three slices were acquired per heart beat in the short axis orientation. The radial acquisition used the following parameters: TR/TE/ α =2.78/1.39/50°, FOV=300x300mm², resolution=2.2x2.2x10mm³, and 88 dynamics per slice. The Cartesian acquisition used the following parameters: TR/TE/ α = 2.91 ms/1.45 ms/50°, field of view = 320x320 mm², resolution = 2.2x2.2x8 mm³, and 65 dynamics per slice. For both rest and exercise stress perfusion protocols, real-time slice tracking navigator was used¹. Radial data were reconstructed using the regularized non-linear inversion with joint estimation of coil sensitivity maps (NLINV)². Cartesian data were reconstructed online using the SENSE reconstruction available on our scanner.

Data Analysis: Two CMR 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).

Results

Figures 2 and 3 show images acquired with the radial and the Cartesian sequences at rest and after physiological stress, respectively. Cartesian and radial NLINV reconstruction yielded comparable image quality for rest perfusion. However, Cartesian sampling led to fold-over artifacts and higher noise compared to radial sampling for stress perfusion imaging. These observations were confirmed qualitatively where radial NLINV reconstruction was scored higher than Cartesian sampling for rest perfusion (1.38 ± 0.62 , vs. 1.81 ± 0.75) as well as for physiological stress perfusion (2.25 ± 0.87 , vs. 2.50 ± 1.16).

Conclusions

Radial sampling outperforms Cartesian sampling for accelerated CMR perfusion after physical exercise using a supine bicycle ergometer.

Acknowledgements

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References

[1] Basha, MRM, 2013, In Press [2] Uecker, MRM, 2008

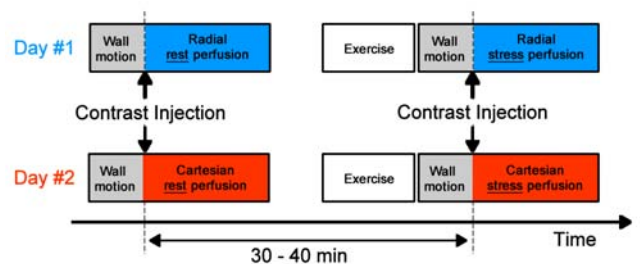


Figure 1. Study protocol. Each subject was scanned twice in two separate days. Rest and exercise stress perfusion scans were performed using radial sampling (Day #1) and Cartesian sampling (Day #2).

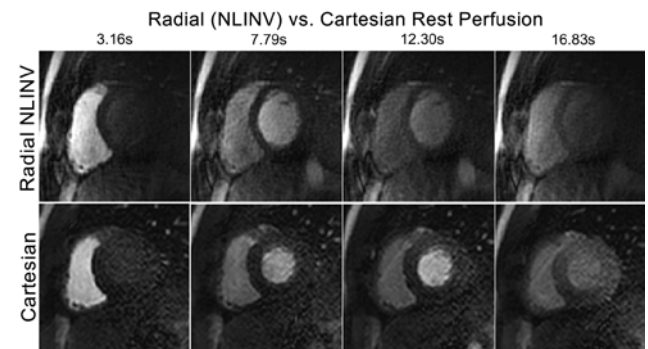


Figure 2. Comparison between radial (top row) and Cartesian (bottom row) rest perfusion at four different temporal dynamics during the first pass of the contrast bolus. The radial images were reconstructed using NLINV; Cartesian images were reconstructed online on the scanner.

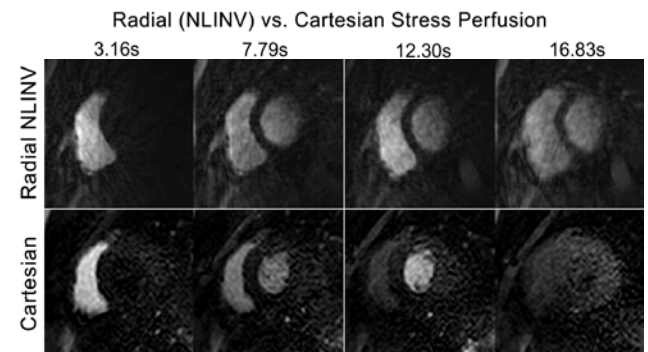


Figure 3. Comparison between radial (top row) and Cartesian (bottom row) stress perfusion at four different temporal dynamics during the first pass of the contrast bolus. The radial images were reconstructed using NLINV; Cartesian images were reconstructed online on the scanner.