Variable-Density Spiral Adenosine Stress Perfusion Imaging Detects Coronary Artery Disease with High Diagnostic Accuracy

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Introduction: Adenosine stress perfusion imaging with CMR has been limited by motion-induced dark-rim artifacts, which may be mistaken for true perfusion abnormalities. We have previously demonstrated that spiral pulse sequences can produce high quality first-pass perfusion images.[1] We have also demonstrated an improved technique using high-resolution variable density (VD) spiral trajectories with a density compensation function that reduces side lobe amplitude further reducing the sensitivity to DRA, while preserving SNR and minimally reducing image resolution [2]. Spiral perfusion pulse sequences have not been evaluated clinically. We aimed to test the clinical performance of a variable density spiral perfusion pulse sequence for the detection of obstructive coronary artery disease (CAD).

Methods: CMR perfusion imaging was performed during adenosine stress (140µg/kg-min) and at rest on a 1.5T MR scanner (Magnetom Avanto, Siemens Healthcare) in 26 subjects scheduled to undergo cardiac catheterization for evaluation of chest pain under an IRB approved protocol. Subjects with prior coronary artery bypass surgery were excluded. Perfusion images were acquired during injection of 0.1mmol/kg Gd-DTPA (Magnevist, Bayer Pharmaceuticals) via peripheral IV with a rate of 4mL/sec at 3 short-axis locations using a saturation recovery (SR) interleaved variable-density spiral pulse sequence with an integrated field-map for off-resonance correction during reconstruction. The VD spiral design was an interleaved linear-in-time trajectory with an initial relative density of 1.2 and a final relative density of 0.4 (where 1 corresponds to Nyquist sampling). Sequence parameters included SR time of 80 ms, TE 1 ms, TR 10 ms, TH 10 mm, FOV 320mm, 8 interleaves, 6.1 ms readout duration, nominal spatial resolution of 2 mm^2. Low resolution field maps were obtained using two single-shot spiral images for off resonance correction with each perfusion image. The flip angle was chosen to have nearly constant magnetization on each interleaf for the given SR time, TR, and expected myocardial T1 values.[1] Images were reconstructed with a fast conjugate-phase semi-automatic reconstruction with Chebyshev approximation of the off-resonance phase term.[3] Images were reconstructed with a conventional (uniform k-space weighting) and a novel DCF (windowed k-space weighting) as described previously.[2] Cine and late gadolinium enhanced (LGE) images were also obtained using standard methodology. All subjects underwent cardiac catheterization following the CMR and significant stenosis was defined as >50%. Two blinded reviewers evaluated CMR images for the presence of perfusion abnormalities consistent with myocardial ischemia. Image quality was graded on a 5 point scale (1 – poor to 5- excellent). Images were also graded for the presence and severity of DRA (0-none, 1-mild, 2-moderate, 3 severe).

Results: Figure 1 shows stress and rest spiral perfusion images from a subject who had normal cardiac function and no LGE on his CMR study. These images clearly show a reversible perfusion abnormality in the anterior wall and anteroseptum and have excellent image quality. This patient was found to have a 90% stenosis in his LAD at cardiac catheterization. Overall the prevalence of obstructive CAD in our study was 65% and LGE was present in 30% of the patients. The average sensitivity, specificity, and accuracy of the two readers were 88%, 89%, and 89% respectively. There was good inter-reader reliability with a kappa statistic of 0.68. The average image quality score was 4.2±0.8 with no studies showing more than minimal DRA. Five studies demonstrated mild dropout artifacts along the epicardial aspect of the inferolateral wall but did not affect diagnostic utility. A few cases demonstrated mild image blurring during first pass of the contrast through the right ventricle, but this resolved prior to enhancement of the left ventricle and myocardium and thus did not impede assessment of perfusion defects.

Conclusions: VD Spiral adenosine stress CMR results in high diagnostic accuracy for the detection of obstructive coronary artery disease with excellent image quality**.** Semi-automatic reconstruction with a Chebyshev semi-automatic reconstruction provides excellent off-resonance performance for this application. Utilization of an optimized DCF resulted in images with high SNR and reduced sensitivity to DRA with minimal reduction in image spatial resolution. We anticipate that given the high SNR of these images, the addition of parallel imaging at relatively low acceleration factors will improve temporal resolution enabling full ventricular coverage with preserved image quality.

References:

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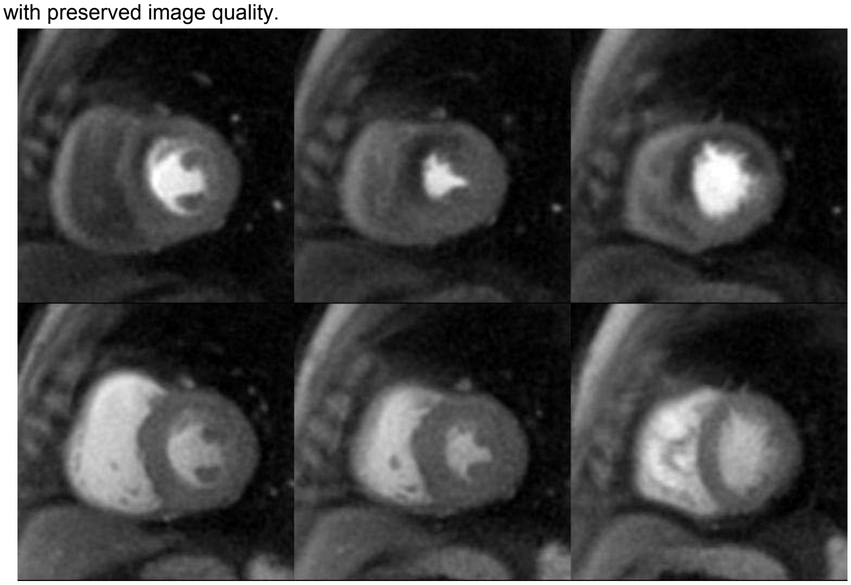

Figure 1: Stress (top) and rest (bottom) perfusion images demonstrate a reversible perfusion defect in the anterior wall and anteroseptum.