QUANTITATIVE SPIRAL PERFUSION IMAGING: INITIAL CLINICAL EXPERIENCE

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Introduction: Adenosine stress perfusion cardiac magnetic resonance (CMR) imaging has become an important tool for diagnosing coronary artery disease (CAD) and may be superior to nuclear myocardial perfusion imaging.[1] Absolute quantification of myocardial perfusion and perfusion reserve (PR) detects a greater burden of ischemia in subjects with multi-vessel CAD as compared to visual analysis and will play an increasingly important role for assessing the need for revascularization.[2] We have developed a spiral pulse sequence for first-pass perfusion imaging and have demonstrated high diagnostic accuracy of this technique for detecting obstructive CAD.[3-4] This sequence can be modified to perform absolute quantification of myocardial perfusion by collecting an arterial input function image (AIF) during the saturation recovery time (SRT) of the first perfusion image without adding any additional imaging time. We demonstrate the preliminary clinical application of this technique in a normal subject, and in two patients with suspected CAD who were scheduled to undergo cardiac catheterization.

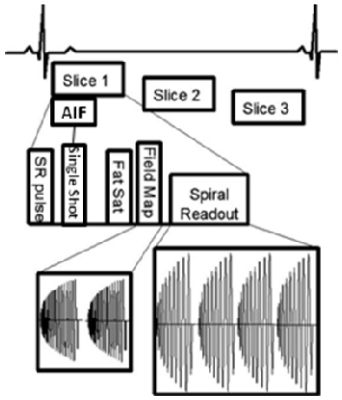
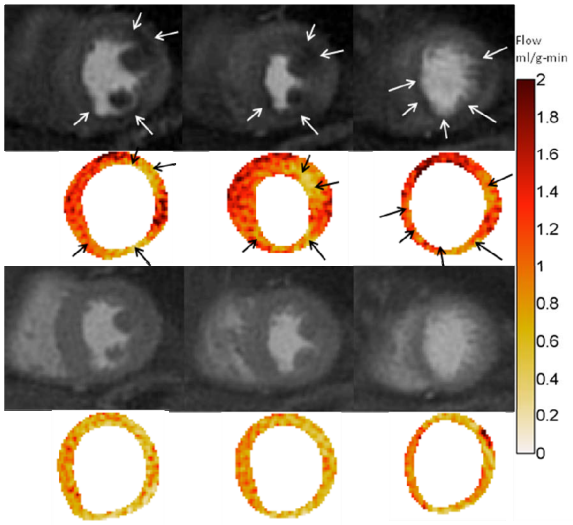


Figure 1: Spiral pulse sequence for quantitative perfusion imaging

Methods: Our previously optimized spiral pulse sequence [4] was modified to acquire proton density (PD) and AIF images to enable quantification of myocardial perfusion (Figure 1). PD images were collected in the first two heart beats utilizing a 5 degree flip angle (FA) and no saturation pulse. Data was collected using a variable density spiral perfusion technique described previously. Sequence parameters included: 8 interleaves, 6.1ms readout per interleaf, TE 1.0ms, TR 9ms, SRT 80ms FA 30°, FOV 320mm^2, in-plane resolution 2.1mm^2. AIF images were acquired during the SRT of the first perfusion image with a 2x accelerated single-shot spiral acquisition using a 90° FA with the following parameters: in-plane resolution 6.95mm^2, SRT 10ms. Resting perfusion images were collected in a normal subject and adenosine stress CMR was performed in two patients scheduled to undergo cardiac catheterization for evaluation of CAD. Perfusion images were acquired at 3 short axis slice locations on a 1.5T Siemens Avanto scanner during injection of 0.1mmol/kg of Gd-DTPA at 4ml/sec. First-Pass stress imaging was performed following a 3 minute infusion of adenosine (140mcg/kg/min). Quantification of perfusion was performed on a pixel-wise basis using Fermi-function deconvolution after image alignment with non-rigid registration.



Results: Resting perfusion maps from a normal subject were uniform and demonstrated a mean resting perfusion of 1.04±0.11 mL/g/min which is close to 1mL/g/min, the expected value for perfusion in a normal subject. The perfusion images and absolute perfusion maps for the first CAD subject are shown in figure 2. There are severe perfusion defects in multiple territories. Globally the stress perfusion was markedly reduced (1.13±0.23 mL/g/min), resting perfusion was also reduced 0.73±0.15mL/g/min, yielding a global perfusion reserve of 1.5 (abnormal). At cardiac catheterization this patient had an occluded right coronary artery, and severe proximal LAD and LCx disease consistent with the quantitative perfusion results. The second CAD subject had a large stress perfusion abnormality in the septum and anterior wall with marked reduction in absolute stress perfusion in this region (Figure 3). Overall the resting perfusion was low at 0.67±0.10 mL/g/min, and the mean stress perfusion was 1.68±0.719 mL/g/min. In the LAD territory the PR was only 1.8 (abnormal), while in the LCx and RCA territories the PR was 3.4 (normal). This patient had a cardiac catheterization which showed a severe proximal LAD stenosis consistent with the perfusion results. In both cases the resting perfusion images appear uniform.

Discussion: Spiral perfusion images have high SNR, are robust to motion-induced artifacts, and have high spatial resolution (2.1mm^2) thus making them ideal for perfusion imaging and pixel-wise absolute quantification of perfusion. As the AIF can be obtained in a single shot during the SRT of the first perfusion slice, quantification does not add any additional time to data acquisition. Our preliminary studies demonstrate homogenous resting perfusion images with a perfusion near 1mL/g/min in normal subjects. In patients with CAD there is good correlation between the regions of reduced stress perfusion, the visual perfusion defects, and the location of obstructive CAD at cardiac catheterization. While this sequence currently only obtains 3 short axis sections per heart beat, the application of temporal compressed sensing and parallel imaging techniques will enable full ventricular coverage quantification. Further validation is ongoing in normal subjects and in patients with chest pain undergoing cardiac catheterization.

Conclusion: We demonstrate for the first time that clinical quantitative adenosine stress perfusion imaging is feasible with spiral-based perfusion techniques. There was good regional correlation between the perfusion images and maps to territories of obstructive CAD at cardiac catheterization.

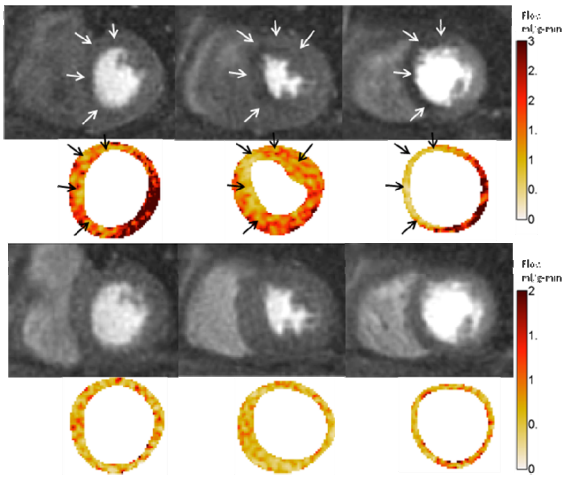


Figure 2. Perfusion images and maps at stress (top) and rest (bottom) from a subject with multi-vessel CAD.

Figure 3. Perfusion images and maps at stress (top) and rest (bottom) in a subject with a severe LAD stenosis.

Reference:

[1] Greenwood JP et al., *Lancet* 379:453- 460 (2012)
[2] Patel et al. *J Am Coll Cardiol. 2010;56(7):561-569*
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