SINGLE-SHOT SPIRAL FIRST-PASS PERFUSION IMAGING: FULL HEART COVERAGE WITH HIGH TEMPORAL RESOLUTION

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Introduction: First-pass cardiac perfusion MRI is a promising modality for noninvasive assessment of coronary artery disease. We have recently demonstrated excellent image quality and diagnostic accuracy of first-pass adenosine stress perfusion imaging using an optimized spiral pulse sequence[1][2]. However, this sequence was only capable of imaging 3 short-axis slices at heart rates up to 110 BPM without parallel imaging. Compressed sensing (CS) [3] is an emerging acceleration technique which is well suited for first-pass perfusion imaging as the representation of the data in the combined temporal and spatial domains is sparse. We have previously demonstrated promising results for 4x accelerated spiral perfusion imaging using CS [4]. We hypothesize that a well-designed single shot spiral first pass perfusion technique using a reconstruction that combines parallel imaging and compressed sensing, such as L1-SPIRIT[4][5], could produce sufficient SNR and image quality to enable multi-slice full coverage of the left ventricle at very high heart rates with very high temporal resolution. Furthermore, the combination of high spatial and temporal resolution will virtually eliminate dark-rim artifacts.

Methods: For dynamic imaging**,** CS requires an incoherent sampling pattern in both spatial and temporal domains. First, we designed a dual-density spiral trajectory (Fig 1a) with an oversampled k-space center (starting density 1.25 for center 10% of trajectory), followed by a broad Fermi-function transition region to an ending density of 0.0625 (16x acceleration) at the k-space edge that results in the point spread function shown in Fig. 1b. The readout duration was only 8ms to minimize off-resonance artifacts [1]. Given that the data is acquired in a single-shot, a 90 degree flip angle was utilized to compensate for the loss of SNR resulting from the high acceleration factor. To provide temporal incoherence, the trajectory was rotated by the golden angle each heart-beat. Resting perfusion images were acquired on a 1.5T Siemens Avanto using 32-channel coil during injection of 0.1mmol/kg of Gd-DTPA in 5 healthy volunteers. Sequence parameters included: TE 1.0ms, TR 1R-R interval, TI 80ms, FA 90^{o}, 6~8 slices depending on heart rate, FOV 320mm, in-plane resolution 2mm, slice thickness 10mm. The time to image a single slice was 88ms, with image data acquired in a single 8ms acquisition.

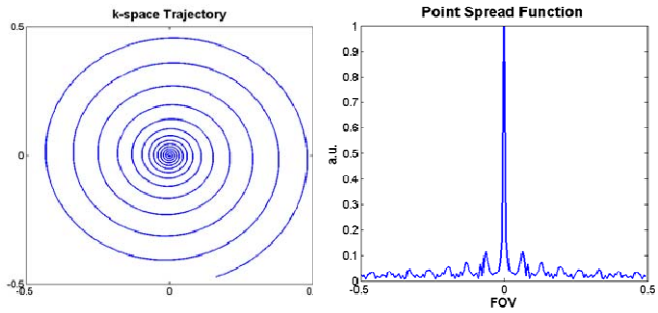

Figure 1. Dual-density k-space trajectory (left) and the point spread function (right)

Proton-density images acquired at the beginning of the acquisition were used to train the SPIRIT calibration kernel. Data reconstruction was performed using an iterative conjugate gradient reconstruction including a data fidelity term, SPIRIT calibration consistency term and an L1-finite difference in time as the sparsifying transform. Reconstruction was implemented in MATLAB.

Results: Figure 2 shows the direct reconstructed images from the single-shot spiral and the L1-SPIRiT reconstructed images. The aliasing pattern in the directed recon image is noise-like and was adequately suppressed using an L1-SPIRiT reconstruction. Figure 3 shows the perfusion images of one subject acquired with this single-shot pulse sequence which enabled acquisition of 7 slices covering the whole ventricular myocardium. There was no dark-rim artifact present in any studies due to the very high temporal and spatial resolution of this pulse sequence.

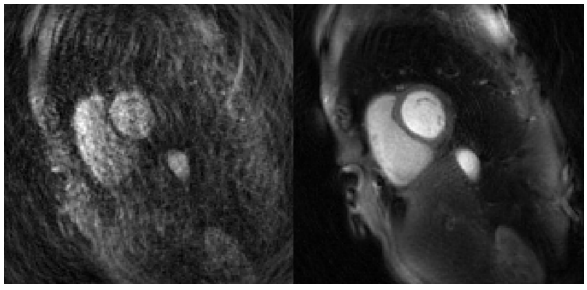

Figure 2. Noise-like alias pattern of directly reconstructed (left) and L1-SPIRiT reconstructed images (right)

Discussion: Single-shot spiral acquisition provides unprecedented temporal resolution for data acquisition with the image data for each perfusion image acquired in <10ms, virtually eliminating motion-induced dark-rim artifacts. If multiple images are acquired after a single saturation pulse, 8 slices covering the whole ventricle can be acquired in less than 160ms. This would enable full heart coverage at any conceivable heart rate. A key to this technique is the ability to use a 90 degree flip-angle to compensate for the SNR loss from both a high acceleration factor and short readout duration. The L1-SPIRIT CS technique provides additional de-noising, thus further improving image SNR and making this technique feasible in the clinical setting.

Conclusion: We demonstrate the for the first time the successful application of a single-shot spiral first-pass myocardial perfusion imaging technique enabling rapid full heart coverage for adenosine stress perfusion imaging, with high spatial and very high temporal resolution. Further optimization of the trajectory and sparsifying transforms, and extension to absolute quantification should enable robust whole heart coverage quantitative perfusion analysis analysis for first pass adenosine stress CMR.

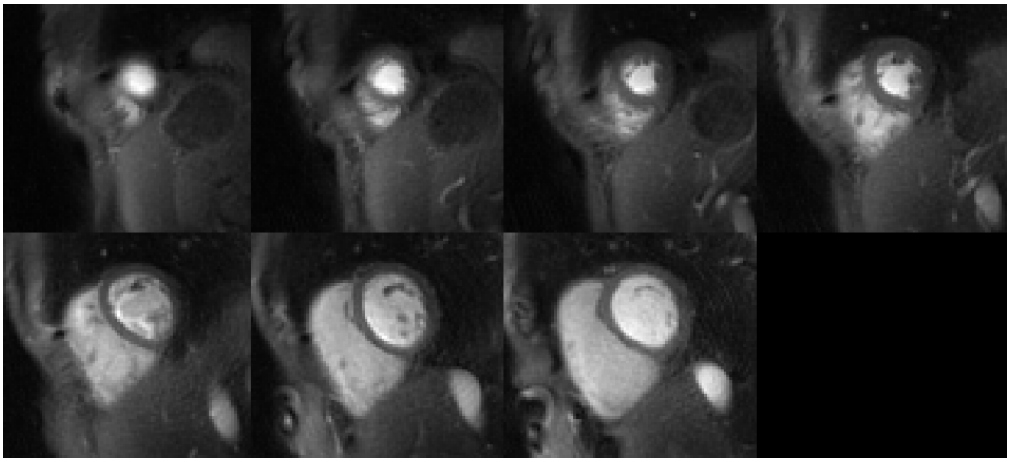

Figure 3. Whole-ventricular coverage perfusion images from one healthy subject. These images were acquired with a single slice following each saturation pulse.

Reference:

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