3D WHOLE-HEART QUANTITATIVE FIRST-PASS PERFUSION IMAGING WITH A STACK-OF SPIRALS TRAJECTORY

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TARGET AUDIENCE: Clinicians and researchers interested in three-dimensional absolute quantitative first-pass myocardial perfusion.

INTRODUCTION: Multi-slices 2D first-pass perfusion imaging has been widely used to diagnose coronary artery disease [1]. Three-dimensional perfusion imaging is an attractive alternative to the 2D multi-slice approach due to its potential advantages of high signal to noise ratio (SNR) and contrast to noise ratio (CNR). Spiral pulse sequences have multiple advantages for myocardial perfusion imaging including high acquisition efficiency, high SNR and robustness to motion. Preliminary studies suggest a 3D stack-of-spiral (SoS) pulse sequence is feasible for first-pass perfusion imaging [2]. There is growing clinical interest in obtaining quantitative, observer-independent, and reproducible measures of myocardial perfusion. Therefore, we have developed an accelerated 3D SoS pulse sequence using motion compensated parallel imaging, compressed sensing,[3-5] and an integrated single-shot arterial input function acquisition (AIF) to perform absolute quantification of myocardial perfusion with whole ventricular coverage.

METHODS: A 4x accelerated 3D SoS trajectory was designed with 3 variable density spirals per partition. Other sequence parameters included: TE 1.0ms, TR 8ms, SRT 80ms FA 30°, 10 partitions over 80 mm slab thickness covering the whole ventricle,, FOV 320mm^2, in-plane resolution 2.1mm, 240ms acquisition window per volume. Additionally proton density images were collected in the first 4 heart beats without a saturation pulse using a 5° FA. AIF images were acquired with a single-shot spiral acquisition using a 90° FA with the following parameters: in-plane resolution 6.95mm, SRT 10ms. Imaging was performed in 4 subjects on a 1.5T Avanto Siemens Scanner during injection of 0.1mmol/kg of Gd-DTPA. Perfusion images were first reconstructed using Block LOw-rank Sparsity with Motion guidance (BLOSM)[5] combined with SENSE, then perfusion images were normalized by the PD images and Bloch simulation was used to convert to absolute concentration-time curves prior to Fermi-function deconvolution. Reconstruction and quantification of perfusion images was performed in MATLAB.

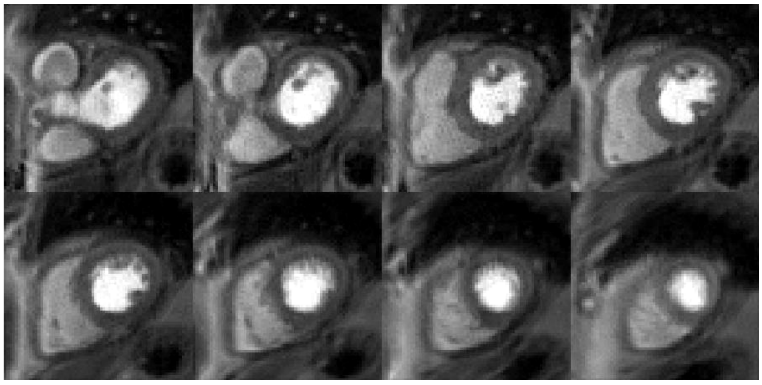

Figure 1. BLOSM-SENSE reconstructed perfusion images

RESULTS: Figure 1 shows BLOSM-SENSE reconstructed perfusion images from one subject acquired with the proposed sequence which enables volumetric acquisition of 8 slices from apex to base covering the whole ventricular myocardium in a 240 ms temporal window. Figure 2 shows the pixel wise myocardial perfusion flow map based on the Fermi deconvolution model. Figure 3 shows the bull-eye segmental perfusion flow maps from the same subject. The mean absolute blood flow was 1.062±0.315 mL/g/min, which is close to 1 mL/g/min expected for a healthy subject.

DISCUSSION: The 3D stacks of spiral perfusion images demonstrate higher SNR as compared to our previous whole-heart multi-slice 2D spiral approach [6]. The resting perfusion measurements are in agreement with the literature and our prior 2D spiral pulse sequence results. The high SNR of a 3D approach improves both the reconstruction quality and benefits pixel-wise perfusion quantification which can be limited by poor SNR. The motion guided BLOSM-SENSE reconstruction improves the robustness of perfusion imaging in the presence of respiratory motion. Preliminary results from retrospective down-sampling of the data indicate that partial-Fourier acceleration in the partition direction will reduce the temporal window below 200ms which should enable robust motion-artifact free 3D imaging at stress heart rates.

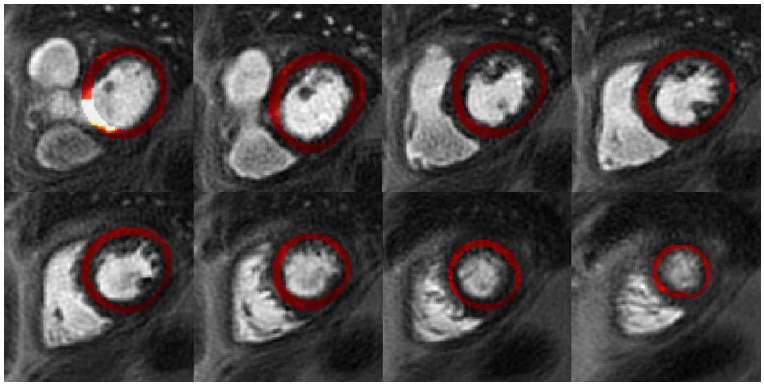

Figure 2. Pixel wise myocardial perfusion map from one healthy subject

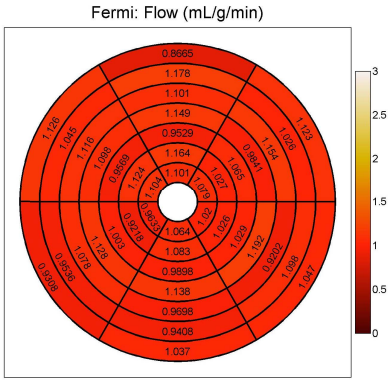

Figure 3. Bull-eye segmental perfusion map

CONCLUSION: We demonstrated the first successful application of 3D absolute quantitative first-pass myocardial perfusion imaging using stacks of spirals in healthy volunteers. This sequence is capable of generating robust quantitative pixel wise myocardial perfusion flow maps covering the entire ventricle which will enable absolute volumetric quantification of ischemic burden. Further validation will be required in patients undergoing adenosine stress CMR.

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