REDUCED FIELD-OF-VIEW SINGLE-SHOT SPIRAL PERFUSION IMAGING

Yang Yang[1], Li Zhao[2], Xiao Chen[1], Peter Shaw[3], Jorge Gonzalez[3], Frederick Epstein[1,4], Craig Meyer[1,4], Christopher Kramer[3,4], and Michael Salerno[3,4]
[1]Biomedical Engineering, University of Virginia, Charlottesville, VA, United States, [2]Radiology, Harvard University, Boston, MA, United States, [3]Medicine, University of Virginia, Charlottesville, VA, United States, [4]Radiology, University of Virginia, Charlottesville, VA, United States

TARGET AUDIENCE: Clinicians and researchers interested in advanced techniques for contrast-enhanced first-pass myocardial perfusion.

INTRODUCTION: Contrast-enhanced first-pass myocardial perfusion is a promising modality for the noninvasive assessment of coronary artery disease (CAD). We have recently demonstrated excellent image quality and diagnostic accuracy of first-pass adenosine stress perfusion imaging using an optimized spiral pulse sequence.[1] We have introduced a single-shot spiral first-pass perfusion imaging pulse sequence capable of whole heart coverage with a temporal foot-print of 8ms per slice, but the technique required 12 fold acceleration to support the usual 340-360mm field-of-view (FOV) needed for clinical imaging. Although the heart only occupies a small fraction of the chest, the k-space trajectory must support a FOV which covers the entire spatial extent of the received signal from the chest to avoid spatial aliasing. Thus, if the region of interest is the heart, sampling the signal from the whole chest is very inefficient. A reduced FOV (rFOV) single-shot spiral perfusion technique would require a lower k-space undersampling factor resulting in reduced spatial aliasing, improved SNR and more robust reconstruction. Thus, the goal of this study was to develop an OVS design suitable for a single-shot spiral perfusion sequence to achieve whole heart coverage with high spatial/temporal resolution.

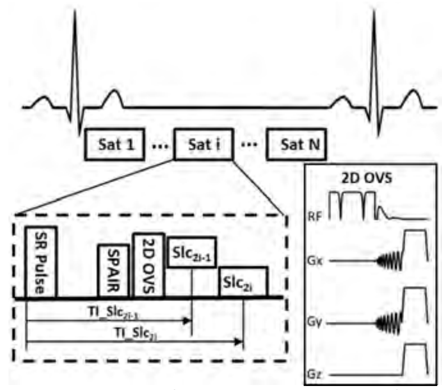

Fig 1. Schematic of the single-shot spiral perfusion with 2D OVS pulse sequence

METHODS: A rFOV single-shot spiral perfusion pulse sequence using a rapid, B1-robust 2D outer volume suppression (OVS) technique[2] was implemented to enable imaging of a FOV that only includes the heart (Figure 1). The OVS preparation consisted of a non-selective adiabatic BIR-4[3] tipdown pulse, a 2D spiral spatial selective[4] tipback pulse and a spoiler applied during the saturation-recovery preparation to suppress signal from outside of a cylindrical region around the heart. Figure 2 shows the jinc-shaped 2D spiral RF pulse with time-bandwidth product of 4 (a) and corresponding gradients (b) to support an rFOV of 100mm. Resting first-pass perfusion was performed in 8 subjects who were undergoing clinically ordered CMR studies with contrast on a 1.5T Avanto Siemens scanner. 2 subjects were scanned using FOV 340mm with highly accelerated spirals (12x Nyq) and 6 subjects of FOV 170mm with moderately accelerated spirals (6x Nyq) to maintain the same spatial resolution of 2mm. Other sequence parameters included: TE 1.0ms, TR 9ms, SRT 80ms, FA 90^o, temporal resolution 8ms each slice. 2 slices per saturation, 8 slices to cover the whole myocardium. The images were reconstructed using Block LOw-rank Sparsity with Motion guidance (BLOSM)[5] combined with SENSE[6].

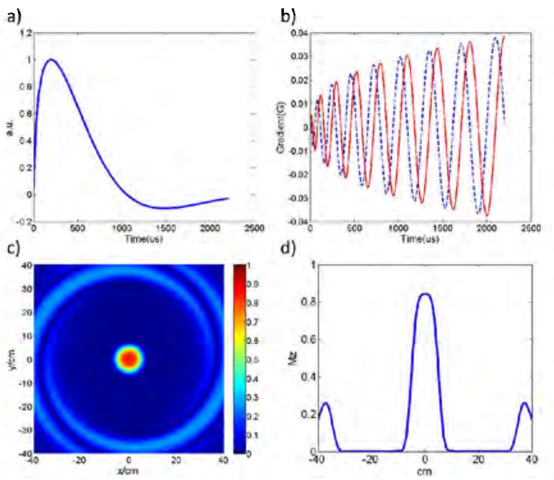

Fig 2. 2D spiral spatial tipback pulse: a) RF, b) gradient, c) 2D spatial profile of rFOV=100mm, d) 1D spatial profile across the center of (c)

RESULTS: The spatial profile of the 2D spiral tipback pulse is shown in Figure 2 (c,d). For the rFOV=100mm design, the stopband is around ±400mm, which is large enough to suppress the signals outside of the heart to prevent spatial aliasing. Figure 3 shows the direct reconstruction (DC) (a) and BLOSM (b) images from 12x accelerated spiral with FOV 340mm without OVS and DC (b) and BLOSM (d) from same spiral trajectory with OVS. The OVS performed well by limiting signal to the heart region. Without OVS, the aliasing was not completely removed due to the very high accelerated factor needed to support a FOV. Figure 4 shows rFOV single-shot spiral perfusion images covering the whole heart from a patient with known CAD. There is a subendocardial perfusion defect in the anterior and lateral walls corresponding to a myocardial infarction on LGE images. Given the temporal footprint of 8ms, fine details of the cardiac trabeculations and papillary muscles are evident which are typically not well visualized due to temporal blurring with other perfusion techniques.

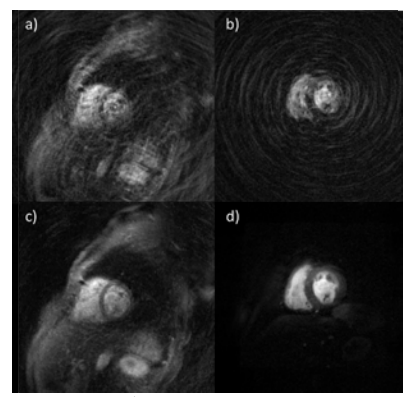

Fig 3. FOV of 340mm w/o OVS (a,c) and w/ OVS (b,d) perfusion images.

DISCUSSION: Spiral tip-back OVS techniques are ideally suited for first-pass perfusion imaging with spiral pulse sequences as they enable a small cylindrical FOV around the heart. The improved sampling efficiency allows for less aggressive spiral acceleration, resulting in higher SNR and reduced residual aliasing artifacts while achieving high spatial/temporal resolution with whole heart coverage. The BLOSM reconstruction enabled motion-insensitive image reconstruction, even in the setting of significant respiratory motion such as free breathing. The 8ms temporal window for each slice made the imaging insensitive to cardiac motion, producing perfusion images with sharp definition of anatomy.

CONCLUSION: We demonstrated the successful application of rFOV single-shot spiral perfusion imaging. The sampling efficiency is highly improved which enables the performance of high spatial/temporal resolution perfusion imaging. Further validation will be required in patients undergoing adenosine stress CMR.

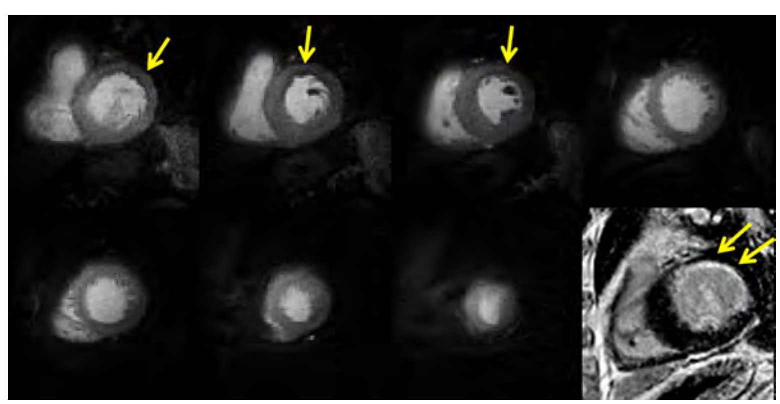
Fig 4. rFOV(170mm) single-shot perfusion and positive LGE images of a CAD patient.

REFERENCES:
[1] Salerno et al. Circ Cardiovasc Imaging 2014;7(4):639-46
[2] Smith et al. Magn Reson Med 2012;67(5):1316-23
[3] Staewen et al. Invest Radiol 1990;25(5):559-67.
[4] Pauly et al. J Magn Reson 2011;213(2):544-57
[5] Chen et al. Magn Reson Med 2014;72(4):1028-38
[6] Pruessmann et al. Magn Reson Med 2001;46(4):638-51