ECG-gated Fast Spin Echo MRA with Interleaved Acquisition of Systolic and Diastolic Data for Improved Robustness to Motion

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Introduction: ECG-gated fast spin-echo based techniques (FSE-MRA) for non-contrast-enhanced MRA applications exploit differences in arterial and venous flow velocity during systole and diastole [1-2]. Due to flow-related dephasing, arteries appear dark in systole, but brighter in diastole when flow is slow. Bright-blood arterial angiograms can be obtained by subtraction. Clinical studies have assessed the diagnostic accuracy of this technique in patients with peripheral arterial occlusive disease [3-5]. When diagnostic quality images are obtained, FSE-MRA demonstrates high accuracy for detection of hemodynamically significant stenosis in the calf. However, poor image quality has been reported in 23% to 47% of assessable segments [3-5], resulting from serious artifacts, among which patient motion is most frequently observed. In FSE-MRA, systolic and diastolic phase datasets are acquired sequentially, over the course of several minutes. Any motion between the two acquisitions can lead to subtraction misregistration, obscuring arteries on the difference image. We hypothesize that interleaving the acquisition of systolic and diastolic partitions may improve robustness to motion. The purpose of this study is to investigate the feasibility of FSE-MRA with systole-diastole interleaving.

Methods: *Technique:* Typically, FSE-MRA data is acquired every cardiac cycle, with diastolic imaging performed at end-diastole with trigger delay (TD) of 0. Systolic data collection occurs during peak-systole with a subject-specific TD, usually 200-300 ms after the R wave trigger. In a sequential regime, TR equals the duration of the cardiac cycle (1RR). However, in an interleaved acquisition, TR alternates between 1RR-TD and 1RR+TD leading to non-uniform T_1 relaxation of background tissue from systolic and diastolic data sets, and potentially suboptimal background suppression upon subtraction. To offset this effect, we perform data collection every other heart beat for improved recovery of longitudinal magnetization. A recent study demonstrated that the inherent sparsity of the FSE-MRA difference image allows for greater acceleration of the acquisition without loss of image quality with generalized autocalibrating partially parallel acquisition (GRAPPA) [6]. To counterbalance the increase in scan time due to the prolonged TR, we utilize the sparsity of the difference image and accelerate the interleaved sequence with GRAPPA factor of 4.

Imaging: The distal lower extremities of 3 healthy volunteers were imaged at 1.5T (Avanto, Siemens). Acquisition parameters included: matrix size = 256x228x64, FOV = 400x352x100 mm^3, voxel size 1.6x1.5x1.6 mm^3, BW 871 Hz/px, TE 21 ms, echo spacing 4.6 ms, constant slice-selective refocusing pulses with FA = 120°. FSE-MRA was performed twice in each subject. A data set with sequentially acquired systolic and diastolic images was obtained with data collection every cardiac cycle (TR = 1RR), GRAPPA factor of 2, and 2 shots per partition. FSE-MRA with interleaved systolic-diastolic partitions was acquired with TR ~2RR, GRAPPA factor of 4, and single shot per partition. Scan time was the same for both techniques and averaged 3-4 mins, depending on heart-rate. In the sequential acquisition, systolic and diastolic data were reconstructed separately, and subtraction was performed on the final magnitude images. In the interleaved case, systolic data were subtracted from diastolic data prior to image reconstruction. To test for tolerance to motion, additional sequential and interleaved data sets were obtained in one volunteer who was instructed to vigorously wiggle their toes 3 to 4 times during each acquisition, while being careful not to displace either extremity from its original position.

Results: FSE-MRA with systolic-diastolic interleaving was successfully acquired in all subjects with excellent image quality. When scanning was performed in the presence of deliberate patient motion, the interleaved acquisition exhibited better tolerance to motion compared to the sequential scan (Fig. 1).

Discussion: This study demonstrates that it is feasible to implement FSE-MRA with systolic-diastolic interleaving without increase in scan time or reduction in image quality compared to a sequential acquisition. One foreseeable challenge of the interleaved acquisition, especially in patients with fast or irregular heart-rate, is the TR variation between subsequent readouts. Our results indicate that collecting data once every 2 heart beats provides sufficient time for magnetization recovery to ensure similar weighting of systolic and diastolic background signal. However, it is necessary to compensate for the resultant decrease in data acquisition efficiency. Our approach is to exploit the sparsity of the difference image and use a higher GRAPPA factor. However, high acceleration factors have been shown to compromise visualization of small arterial branches [6], which may prove to be a limitation when disease is present. Evaluation in a large clinical population is warranted to verify whether an the proposed interleaved acquisition improves robustness to motion, while maintaining image quality; however, initial results in a volunteer, performing controlled movements, are promising.

References: [1] VJ Wedeen, et al., Science 1985, 4728, 946-8. [2] Miyazaki M, et al., Radiology 2003, 227:890-896. [3] Lim RP, et al., JMRI 28: 181-184. [4] Li D, et al., Eur Radiol 2011, 21:1311-22. [5] Haneder S, et al., Eur Radiol 2011, 21: 1452-61 [6] Storey P, et al., MRM 2011 (In Press)

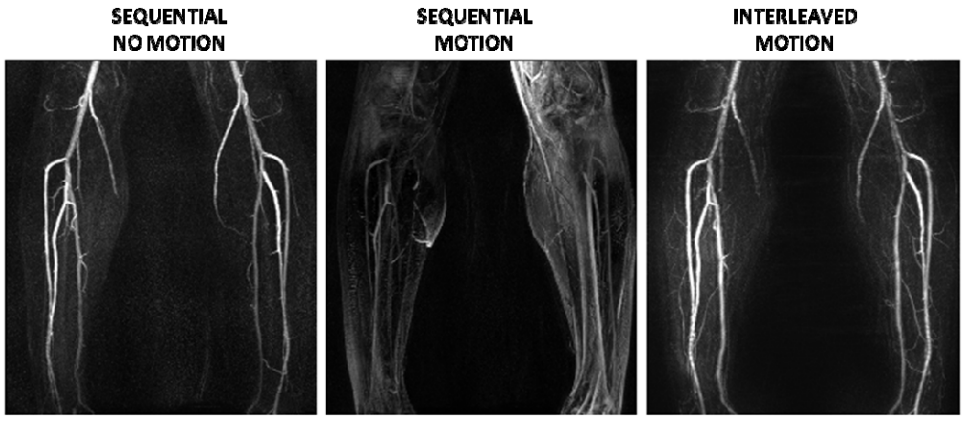

Fig. 1 FSE-MRA angiograms obtained in a health volunteer illustrate better tolerance to motion with systolic-diastolic interleaving