MYOCARDIAL PERFUSION IMAGING USING TRANSIENT-PHASE SPIRAL-IN/OUT SSFP

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Introduction: Myocardial first-pass perfusion imaging is a promising diagnostic tool for the assessment of ischemic heart disease. Most studies utilize a saturation recovery (SR) preparation for T1 weighting and a spoiled GRE readout module. Spiral imaging, due to its high acquisition speed and robustness against motion artifacts, has been successfully adopted in this application combined with the SR GRE sequence using the traditional spiral-out trajectory [1]. SR combined with a transient SSFP readout is an alternative sequence that can provide higher SNR [2-3]. The spiral-in/out bSSFP sequence is advantageous over the traditional spiral-out bSSFP sequence since it can take advantage of the refocusing mechanism at TE = TR/2 to increase SNR and automatically achieve first gradient moment nulling due to symmetry as shown in [4]. Therefore, in this study we aim to combine the spiral-in/out trajectory with the SR SSFP sequence and acquire perfusion data in the transient phase.

Methods: The spiral-in/out SR SSFP sequence was designed to match the spatial resolution and coverage of the spiral-out SR GRE sequence [1]. The corresponding sequence parameters of both sequences are given in Table 1. For the SR SSFP, no dummy pulses are applied before acquisition except for an initial $\alpha/2$ pulse. The signal intensity of blood with 1 mmol/L Gd at each following TR was simulated and compared with the SR GRE sequence. To study off resonance effects during the transient phase of SR SSFP, the signal intensity and phase as a function of the off resonance frequencies were also simulated and compared with steady-state SR SSFP.

Sequence	Samples	Interleaves	TR (ms)	TE	Mat. Size	FA
SR SSFP	800	32	3.65	1.82	144*144	46
SR GRE	4096	8	10.85	0.94	180*180	30

Table 1. Sequence parameters of SR SSFP and SR GRE

Initial studies were performed in two subjects on a Siemens Avanto 1.5 T scanner using the spiral-in/out SR SSFP sequence with informed consent from the patients under the local IRB. Perfusion images at three short axis slice locations were acquired during and after injection of 0.1 mmol/kg of Gd during an expiratory breath-hold. SPIRiT image reconstruction [5] was used with a variable density spiral k-space trajectory to reduce aliasing and increase the supported FOV. The k-space density varied linearly with time starting at 1.2 x Nyquist and ending at 0.4 x Nyquist.

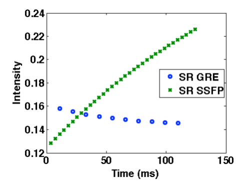

Figure 1. Simulated intensity of SR SSFP and SR GRE

Results: Figure 1 shows the simulated signal intensity of the SR SSFP and SR GRE sequences as a function of acquisition time. The total time to acquire each slice of the SR SSFP is slightly longer than SR GRE due to the increased number of interleaves. SR SSFP starts with a lower intensity than SR GRE but increases with the time. The mean intensity of SR SSFP is greater than SR GRE, which will result a higher SNR, as validated in [2]. Figure 2 shows the simulated mean signal intensity (left) and phase (right) as a function of off resonance frequency during the transient phase used for data acquisition and the final steady state. The transient phase suffers less from the banding artifacts and intra-voxel signal cancellation as the trough in the left curve is much shallower and the water and fat are not in completely opposite phases.

Figure 3 shows one patient study result at rest. Eight frames at every other heartbeat of the apex (first row), mid (second row) and basal (third row) short axis slices were selected and displayed here. 50 frames were acquired in total with one frame per heartbeat. The apex slice demonstrates a perfusion defect in the anteroseptum. The mid ventricular slice also shows minor perfusion defects near the RV insertion site. This patient was known to have severe multi-vessel CAD with presumed resting ischemia.

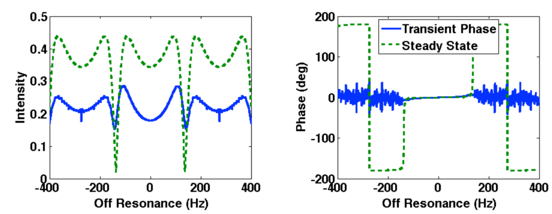

Figure 2. Simulated intensity and phase as a function of off resonance frequency of SR SSFP during the transient phase and the steady state.

Discussion: In this study spiral-in/out SR SSFP during the transient phase was implemented and tested on the scanner. The simulation study shows improved SNR of this sequence as compared with the spiral-out SR GRE sequence. The spatial resolution of the SR-SSFP was lower than SR-GRE due to lower spiral k-space velocity, which accounted for some of the experimental SNR improvement. However, simulations indicate that the signal level would still be higher with the spatial resolution of SP-SSFP matched to that of the SR-GRE sequence. The flip angle of SR SSFP was chosen to be 46° due to SAR limitations, even though a higher flip angle can further increase the signal intensity in the transient phase in theory. The signal intensity and phase were also simulated and showed an increased robustness to off-resonance of SR SSFP during the transient phase compared to steady-state SR SSFP. Initial application of the SR SSFP shows promising results. In the future, temporal redundancy can be exploited to reduce the scan time of one slice. Whole heart coverage with more 2D slices or 3D encoding is the ultimate goal of this study.

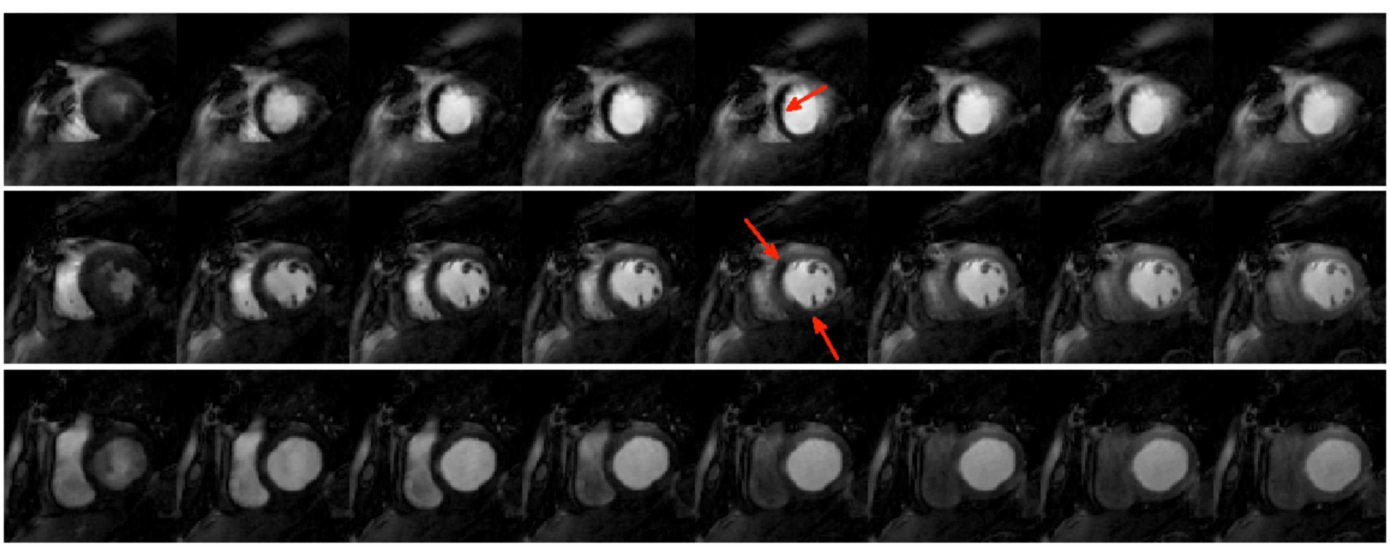

Figure 3. Patient perfusion result showing three short axis slices (apex to basal from top to bottom row) and perfusion defects.

References: [1] Salerno M, et al. MRM 65: 1602-10 2011. [2] Wang Y, et al. MRM 54: 1123-9 2005. [3] Scheffler K. MRM 49:781-3 2003. [4] Feng X, et al. ISMRM 2011: p2620. [5] Lustig M, et al. MRM 64: 451-77 2010.

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