A Fast Flow Compensation Technique for Self-Gated Sequences

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Introduction

In cardiac imaging, a trigger signal is derived from the ECG to synchronize MR data acquisition with heart motion. In small animals ECG signal acquisition is often challenging, and alternative triggering methods are applied for synchronization. Self-gating is a very elegant approach for synchronization as it uses information extracted from an additional short, non-spatially encoded data acquisition which is integrated into the pulse sequence. Major advantages of self-gating are that no additional hardware is required, that breathing motion information can also be extracted and that the (typically) retrospective reconstruction can yield data sets with high temporal resolution in the cardiac cycle.

When implemented in combination with flow compensation, which is necessary for cardiac imaging, pulse sequences with self-gating tend to get significantly longer than ordinary cardiac pulse sequences with similar parameters. In this work we suggest a new flow compensation scheme optimized for self-gating sequences that has very little or no time penalty over self-gating sequences without flow compensation, and thus allows increasing the temporal resolution in the cardiac cycle.

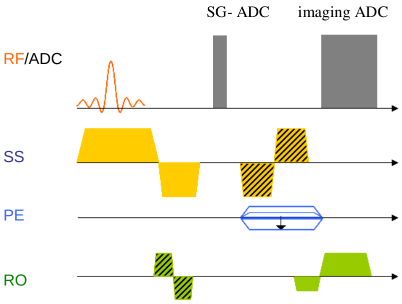

Fig. 1: Schematic of the 2D self-gated FLASH sequence with time-efficient flow compensation. The bipolar flow-compensating gradients in slice selection (SS) and readout (RO) direction are dashed. In phase-encoding (PE) direction no flow compensation was implemented.

Materials and Methods

Pulse Sequence Development

A self-gated 2D FLASH sequence without flow compensation (noFC) was implemented where the self-gating ADC (SG-ADC) was placed after the rewinder gradient in slice selection direction and prior to the dephasing gradient in readout direction [1]. Conventional flow compensation gradients were added in a second variant (cFC) in both slice selection and readout direction, which were played out before and after the SG-ADC, respectively. Finally, the new short flow compensation (sFC) according to Fig. 1 was implemented. Here, flow compensation gradients are inserted into the noFC-sequence as bipolar gradients after (slice selection) and before (readout direction) the SG-ADC to null the first moment only during image data acquisition. Thus, the phase of the SG-ADC is still motion-sensitive, while the imaging ADC acquires motion-compensated data. Fig. 2 illustrates the increase in time-efficiency of the sFC over the cFC implementation.

Animal Imaging Protocols

Self-gating measurements were carried out in mice with all three sequences on a clinical 1.5 T MR system (Siemens Symphony, Erlangen, Germany) using a home-built small animal Tx/Rx coil. The following parameters were used: FOV = 50×50 mm^2, matrix = 256×256, slice thickness = 1.5 mm, α = 25°, BW = 130 Hz/pixel, repetitions = 30. The minimum TR and TE for the three pulse sequences were: TR/ TE = 17/7.6 ms (noFC), 21/11.2 ms (cFC), and 18/8.64 ms (sFC). This led to a total scanning time of 130 s (noFC), 162 s (cFC), and 139 s (sFC). The motion-sensitivity in the noFC and sFC technique are VENC = 21 cm/s and 86 cm/s in slice selection and readout direction, respectively.

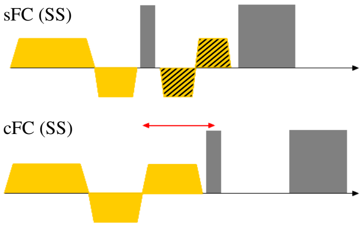

Fig. 2: Comparison of the sFC and the cFC implementation slice selection direction. The red arrow indicates the additional time required for flow compensation in cFC.

Results and Discussion

In the animal measurements a heart cycle duration of the mouse of about 230 ms was observed. With the minimum TE/TR values, the following number of heart phases could thus be reconstructed: 16 (noFC), 13 (cFC), and 15 (sFC). Due to restrictions in the dB/dt monitoring, which could not be deactivated for the experiments on the whole body MR system, TE/TR needed to be increased and the number of phases was reduced to 13 (noFC), 10 (cFC) and 12 (sFC). The sFC implementation does not have the same TR as the noFC sequence because e.g. the duration of the bipolar flow compensation gradients in readout direction slightly exceeds the duration of the slice rewinder gradient plus the ramp down time of the slice selection gradient. Nevertheless, even with the restrictions in gradient slew rate 20 % more phases can be reconstructed with the sFC as compared to the cFC. In Fig. 3 only two phases are shown for each sequence version to demonstrate the effectiveness of the flow compensation. Both flow compensated variants significantly reduce the flow artifacts.

In contrast to the cFC implementation, the first moment in the SG-ADC signal of the sFC implementation is not zero, which might increase phase variations of the SG signal. It remains to be investigated whether these phase variation can be used to further optimize the analysis of the self-gating trigger signal.

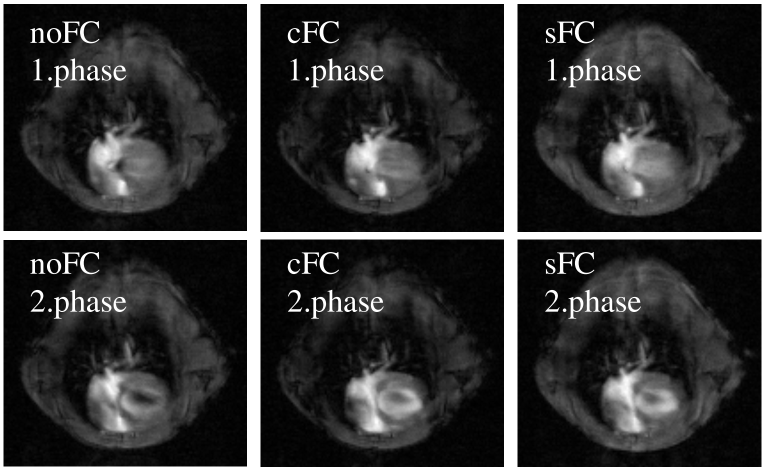

Fig. 3: Two heart phases from a measurement without flow compensation (noFC), with conventional flow compensation (cFC) and with short flow compensation (sFC) were reconstructed. The images clearly show that both flow compensation techniques significantly reduce flow artifacts.

Acknowledgements

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References

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