Startup Method for Magnetization-Prepared SSFP cine imaging

J. Zwanenburg¹, J. Kuijer¹, J. Marcus¹, R. Heethaar¹
¹VU University Medical Center, Amsterdam, Noord-Holland, Netherlands

Abstract  A startup method is presented to combine steady state free precession (SSFP) cine imaging with tissue tagging. The method consists of linearly increasing startup flip angles (LISA), together with interleaved segmented k-space ordering, and was compared with the standard \( \alpha/2 \) startup method. Unlike the \( \alpha/2 \) method, LISA was not prone to artifacts from spins that are far off-resonance due to chemical shift or field inhomogeneities. With LISA-SSFP, ghost artifacts from the interruption of the steady state were negligible, even in the first cine image obtained immediately after the application of the tissue tagging.

Introduction  It has been shown that SSFP imaging with myocardial tagging yields better tagging contrast to noise ratio and better tag persistence than spoiled gradient echo imaging (1). However, to apply myocardial tagging, the steady state must be interrupted after each ECG-R wave, which leads to image artifacts unless an appropriate startup method is used. This work presents a startup method that yields artifact free SSFP images directly after the application of the tagging preparation pulses.

Method  After each ECG-R wave, the \( \pm \alpha \) pulse train is interrupted by an \( \alpha/2 \) flip-back pulse, followed by the magnetization preparation. Imaging is started with \( n \) pulses with linearly increasing startup flip angles (LISA) (2). Data acquisition begins with the first pulse after the magnetization preparation. We used interleaved segmented k-space reordering (3) to prevent ghosting from the increasing signal during the LISA rampup. This LISA startup method was compared with the standard \( \alpha/2 \) startup method (4).

MR imaging was performed on a 1.5 T whole body scanner (Magnetom Sonata, Siemens, Erlangen, Germany). Mid-ventricular short-axis cines were measured on 6 healthy volunteers with both LISA-SSFP and \( \alpha/2 \)-SSFP. Magnetization preparation consisted of sinusoidal modulation of the tissue magnetization (5), or of dummy preparation to image ghost artifacts more clearly. The imaging parameters were: \( \alpha = 20^\circ \), voxel size 1.2 x 3.9 x 6.0 mm³, BW 369 Hz/pixel, TE/TR = 2.34/4.68 ms, and 11 ky/beat (temporal resolution = 51 ms). The number of LISA pulses was 10.

Results  Figure 1 shows the images obtained immediately after magnetization preparation. The results are shown for a volunteer with a considerable amount of subcutaneous fat, of which the spins are opposed-phase spins due to chemical shift. With the \( \alpha/2 \) startup method, the opposed-phase spins lead to severe ghosting, even across the myocardium. Also the second cine image showed some ghost artifacts from opposed-phase spins with the \( \alpha/2 \) startup for this volunteer. With the LISA startup method, however, no ghosts originate from these opposed-phase spins. The other volunteers gave similar results, though the ghost artifacts for the \( \alpha/2 \) startup method were less pronounced when less subcutaneous fat was present. The lower flip angles during LISA lead to a reduced SNR of about 40 % in the image obtained during the LISA rampup. However, since the tag amplitude is largest in the first image, the tag contrast to noise ratio is still good, as can be seen from the figure.

Conclusion  With LISA-SSFP, no ghost artifacts originate from the interruption of the steady state, even when data acquisition starts right after the application of magnetization preparation.


Acknowledgment  This work was supported by the Netherlands Heart Foundation, grant 2000B220.

FIG. 1. First SSFP cine image after magnetization preparation. Top: dummy magnetization preparation. Bottom: tissue tagging. The images were acquired with interleaved k-space ordering. Phase encoding was in the horizontal direction, parallel to the tag lines.