Acquisition of Black-blood Cine Cardiac Images in a Single Heartbeat at 3.0T

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Introduction: Stimulated echo mode (STEAM) imaging can generate quality cine black-blood images of the heart as has been shown recently by Fahmy et al. The method requires the acquisition of two sets of STEAM images with two different demodulations in order to correct deformation-induced artifacts. Because of the splitting of the image acquisition over several cardiac cycles, the method requires cardiac gating and at least one breath-hold in order to acquire the entire cine sequence. The need of cardiac gating and breath-holding makes the method vulnerable to artifacts generated by irregular R-R intervals (arrhythmia) and improper breath-holding. In addition, examining patients undergoing administration of dobutamine, i.e. stress test, was not appropriate. In this work, we present a fast acquisition of the STEAM images to produce black-blood cine sequences of the heart acquired in a period of a single cardiac cycle. The method was tested on normal volunteers and patients using Intera 3.0T system (Philips Medical sys.).

Methods: The presented STEAM sequence uses efficient techniques for fat suppression and k-space excitation and acquisition in order to acquire one image in 44ms (capture 20 frames in a single cardiac cycle with heart rate=75pbm). First, a fat suppression consisting of only one fat-saturation pulse applied prior to the STEAM modulation is applied (as shown in Figure 1). Consequently, no fat suppression pulses are needed during the acquisition of images, which saves a significant amount of time than the current fat suppression techniques (Fahmy et al). In order to reduce the acquisition time further, spatially-selective modulating RF pulses are used to modulate a small region of interest (ROI) around the heart, which allows imaging of a reduced FOV, i.e. traversing the k-space using sparse trajectories, without aliasing artifacts (for more details, see Pan et al). In the current technique, interleaved multi-shot spiral acquisitions are used to provide fast acquisition with reasonable image quality. To maintain constant myocardial signal intensity throughout the cardiac cycle, a ramped flip angle, **α,** is used to compensate for the T1-related signal decay.

Results and Discussion: Figure 2 shows the acquired images at four time frames. The imaging parameters are slice thickness 8mm, 22 cardiac phases (44 ms/image), rFOV 160mm, max flip angle 40^{o}, and STEAM modulation frequency 0.3 mm^{-1}. High contrast between the myocardium and the blood can be shown throughout the entire cardiac cycle with high quality despite the expected field inhomogeneity in a 3.0T magnet.

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References: Fahmy A.S., et al. *Proc. of* SCMR, San Francisco (Jan. 2005). Pan L., et al. *Proc. of* SCMR, San Francisco (Jan. 2005).

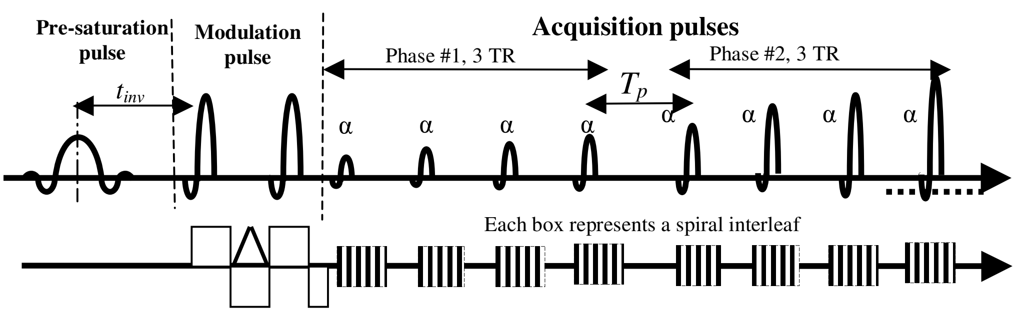

Figure 1. The pulse diagram of the proposed cine black-blood sequence. A fat-selective pre-saturation pulse is applied prior to the modulation pulse resulting in suppression of the fat in the stimulated echo. Acquiring one image consists of 4 shots of spiral interleaves. The flip angle is incremented to compensate the expected signal decay caused by T1 relaxation.

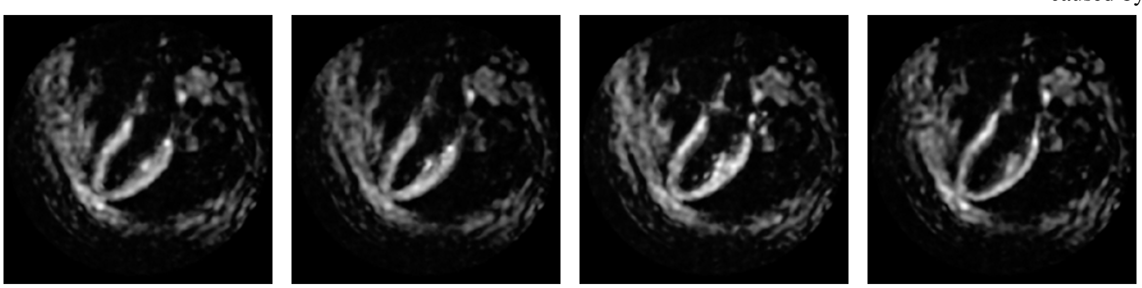

Figure 2. Four time frames selected from a cine sequence of the heart of a normal volunteer. The reference of time stamps is taken as the R-wave of the ECG.