Dark Blood bSSFP Cardiac MRI using HEFEWEIZEN

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INTRODUCTION: Multiple cardiac pathologies require a "dark blood" sequence to highlight myocardial abnormalities. For example, T2-weighted dark blood prepared turbo spin echo (TSE) sequences are often used to image cardiac edema (1). One primary limitation of these methods is the long acquisition time, resulting in potential image degradation from cardiac or respiratory motion. Here we use a new dark blood imaging technique called 'Halting the effects of flow enhancement with effective intermittent zeugmatographic encoding' (HEFEWEIZEN) (2) to provide dark-blood cardiac images with the potential for rapid imaging. The HEFEWEIZEN sequence is built with an underlying bSSFP framework in which the spatial encoding gradients in some TR blocks are replaced by spatially selective saturation pulses resulting in directional suppression of the flowing blood signal (2). We build from the earlier ungated method used in carotid arteries to show here that the HEFEWEIZEN sequence can also be segmented and gated for rapid dark blood cardiac imaging.

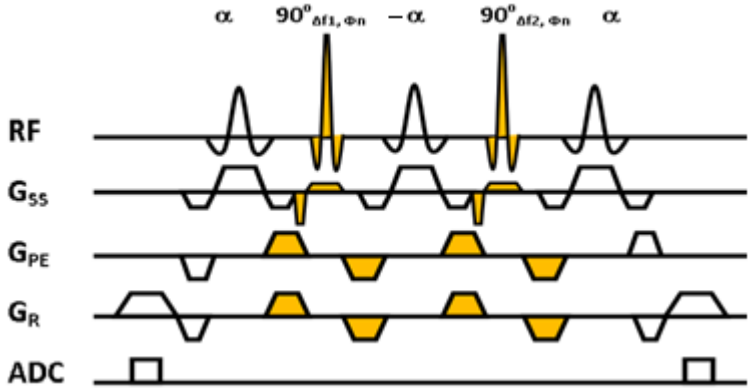

Fig 1: bSSFP based HEFEWEIZEN dark blood pulse sequence

METHODS: The HEFEWEIZEN (Figure 1) and TrueFISP sequences were used to image 3 asymptomatic volunteers in this IRB approved study. Both sequences were segmented and images were acquired within the diastole phase of the cardiac cycle using ECG gating. An α/2 preparation pulse was used to place the magnetization in steady state. Magnetization was stored at the end of each segment by another α/2 pulse. Experiments were performed on a 1.5T MRI scanner (Siemens Espree, Erlangen, Germany) using 6 element flexible body matrix and 24 element spine matrix coils (with auto-coil select enabled). The segmented HEFEWEIZEN sequence parameters included: TR = 3.4 ms, TE = 1.7 ms, imaging matrix = 128 X 128, segments = 2 (64 lines each), slices = 5, flip angle = 50°, ECG trigger delay = 500 ms, saturation slab thickness = 200 mm, saturation gap = 20 mm and dark blood preparation every 6 readouts. Blood flow signal was suppressed above and below the imaging slice. Control images were acquired using an equivalent multi-slice TrueFISP sequence without the inclusion of saturation pulses. Once the images are acquired, region-of-interest (ROI) analysis was performed over the left and right ventricles and myocardium muscle wall to determine mean percentage suppression values.

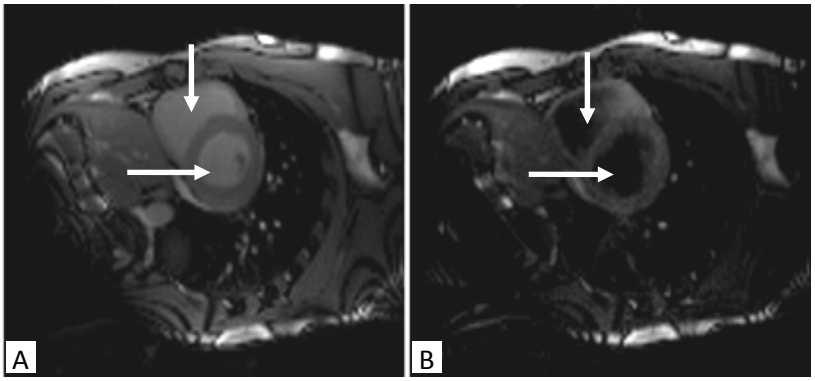

Fig 2: Short axis cardiac images from a normal volunteer. (A) segmented True-FISP (B) segmented HEFEWEIZEN sequence images. Horizontal and vertical arrows indicate the left and right ventricle respectively. Unsuppressed blood signal is seen in the segmented TrueFISP image (A). Blood signal is saturated in the new segmented HEFEWEIZEN image (B).

RESULTS: Figure 2 shows a single slice short axis cardiac image in a normal volunteer using both the segmented True-FISP (A) and the new segmented HEFEWEIZEN (B) sequences acquired in 0.58 and 0.77 seconds per slice respectively. The segmented HEFEWEIZEN sequence maintains bSSFP contrast while simultaneously suppressing the bright blood flow into the ventricles. Initial ROI analysis demonstrated average blood flow signal suppression values of 65% in the right ventricle and 75% in the left ventricle and stationary tissue suppression of 44% in the myocardium muscle walls.

DISCUSSION: A new application of a fast, high SNR dark blood prepared TrueFISP sequence (HEFEWEIZEN) now segmented and gated has been shown to suppress the blood flow signal (>65%) in the cardiac ventricles with a 0.19 second increase per slice in image acquisition time over a segmented non-prepared True-FISP sequence with the same imaging parameters. bSSFP stationary tissue contrast is maintained in the non-vascular tissues while offering an increased acquisition speed as compared to dark blood prepared turbo spin echo. Future work will include an optimization of the imaging parameters like saturation slab thickness, saturation gap, dark blood preparation over different ECG trigger delays and the number of segments.

CONCLUSION: HEFEWEIZEN, a fast, high SNR, dark blood prepared TrueFISP sequence with segmentation and gating, has been shown to provide suppressed blood signal images under the additional demands of cardiac motion and complex blood flows though at a cost of some background tissue suppression as well.

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REFERENCES: (1) Simonetti OP, et al.: Radiology 1996; 199:49-57
(2) Derakhshan JJ, et al.: JMRI 2009; 29:1163-1174