Correcting Motion Artifacts in Stimulated Echo Mode (STEAM) Cardiac Imaging

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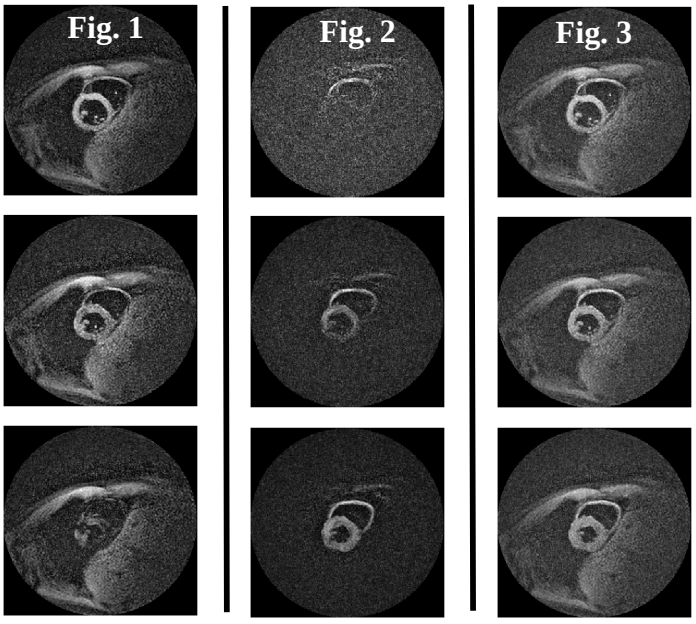
Introduction: STEAM imaging of the heart is useful for generating black blood images of the heart. However, its application for acquiring cine movies during cardiac cycle was hampered by non-uniform loss of signal intensity inside the myocardium[1]. The STEAM sequence is based on modulating the longitudinal magnetization of the tissue with a sinusoidal pattern of frequency $f_m(x,y)= f_o$, where f_o is a constant determined by an applied modulation gradient. During image acquisition, a constant demodulation frequency, $f_d=f_o$, is used to refocus the magnetization and thus a stimulated echo is measured. Nevertheless, due to myocardial deformation, the modulation frequency $f_m(x,y)$ becomes spatially-variant, and $f_d=f_o$ cannot completely refocus the magnetization at all pixels; thus, loss of myocardial signal. In this work, we present a method to recover the signal loss caused by tissue deformation in STEAM sequences.

Method: Two STEAM images (I_L and I_H) of the same anatomical slice are acquired with two different demodulation frequencies f_L and f_H. The frequencies f_L and f_H are selected such that $f_L < f_m(x,y) < f_H$. The selection of these two demodulation frequencies guarantees that the signal loss in one image is recovered by the other one. The summation (I_L+I_H) reduces the change of intensity due tissue deformation, but not completely. Further improvement is done by multiplying the summation by a spatially dependent map whose value at each pixel is determined by the amount of tissue deformation (computed from the two intensity values of the pixel in the acquired images I_L and I_H [2].

Experiments: Short axis images of a healthy volunteer's heart were obtained using fast STEAM sequence[3]. The images were acquired using spiral acquisition (12 interleaves) on an Intera 1.5 Tesla scanner (Phillips Medical Systems, Best). The imaging parameters are slice thickness=10mm, 25 cardiac phases, FOV=350mm, flip angle=40^o, and modulation frequency f_o=0.3 mm^{-1}. Modulation of magnetization was applied at end diastole and thus $f_L= f_o$ was used since no further stretch of the myocardium was expected. Also, assuming a maximum contraction of the myocardium=25%, a demodulation frequency f_H=1.33 f_o was used.

Results and discussion: Figures 1 and 2 show images acquired with $f_d=f_L$ and $f_d=f_H$, respectively. Standard STEAM image acquisition (with $f_d=f_L$) suffers from losing the myocardium signal with contraction. Images acquired with $f_d=f_H$ have the situation reversed and the myocardium signal increases with contraction. Combining the two images, as discussed above, compensates the loss of the myocardium signal and shows high contrast between the myocardium and the blood throughout the entire cardiac cycle (Figure 3).

Conclusion: The proposed method enables functional STEAM imaging of the heart without signal-loss due to tissue deformation.



Figures 1-3 Short axis images of the human heart using a high-speed STEAM pulse sequence (3 time frames). Images in Fig. 1 and 2 were acquired with $f_L= f_o$, and f_H=1.33 f_o respectively. Images in Fig 3 are the result of combining the corresponding images in the other two columns as described in the text.

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References:

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