Myocardial Tagging Contrast without Fading in Cine SSFP Images

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INTRODUCTION

MRI tagging is useful for non-invasive assessment of tissue motion. Steady State Free Precession (SSFP) has been considered for imaging tagged myocardium because SSFP has many advantages including high Signal to Noise Ratio (SNR) and short imaging time [1]. However, in cine images, the tagging contrast decays at later cardiac phases. In this work, a method is proposed that makes use of the magnetization vector trajectory in SSFP in order to improve tagging contrast throughout the whole cardiac cycle.

THEORY and EXPERIMENTS

In SSFP, the transition into steady state for on-resonance spins can be approximated by an exponential decay [2] with rate $\eta = E_1 \cos^2(\varphi/2) + E_2 \sin^2(\varphi/2)$ (short TR assumption was used) , where $E_1 = e^{-\Delta T/T_1}$, $E_2 = e^{-\Delta T/T_2}$, φ is the flip angle of the RF pulse, and ΔT is the time duration within the heart phase interval during which the magnetization vector experiences an exponential decay. The proposed method makes use of the magnetization vector trajectory in SSFP in order to recursively increase the flip angles of each heart phase for the sake of keeping a constant tagging contrast. Figure 1 shows the position of the magnetization vector after relaxation and before applying the new RF pulse, as well as after applying the new RF pulse [3]. Solving recursively for the flip angles from one heart phase to the next one, we obtain the following formula: Assuming that the initial flip angle is $\varphi_0 = \varphi$, then $\varphi_n = 2\beta_n$, where $\beta_0 = \varphi/2$ and $\beta_n = \sin^{-1}\left(\frac{\sin(\beta_{n-1})}{E_1\cos^2(\beta_{n-1}) + E_2\sin^2(\beta_{n-1})}\right)$.

A phantom and a human volunteer were scanned on a 1.5T scanner (Philips Gyroscan Intera). Before the magnetization preparation periods, the magnetization vector was stored in the longitudinal direction, then after the preparation period, it was restored back using half the new flip angle. The T1 relaxation during the preparation periods is taken into consideration when calculating the flip angles of the next heart phase. The experimental parameters are: FOV = 350×246 mm, matrix = 176×128, slice thickness 10 mm, and TRR = 750 ms. For the phantom experiment, BW = 487 Hz/pixel and TR = 3.65 ms, while for the *in-vivo* experiment, BW = 1180 Hz/pixel and TR = 2.98 ms.

RESULTS

The resulting phantom and *in-vivo* images are shown in figures 2 and 3, where the top row shows the cine images acquired with the same flip angle for all heart phases, while in the second row, the flip angles are increased from one heart phase to another using the proposed method. Tagging Contrast to Noise Ratio (TagCNR) is calculated, as well as simumlated, for the phantom images and the results are shown in figure 4.

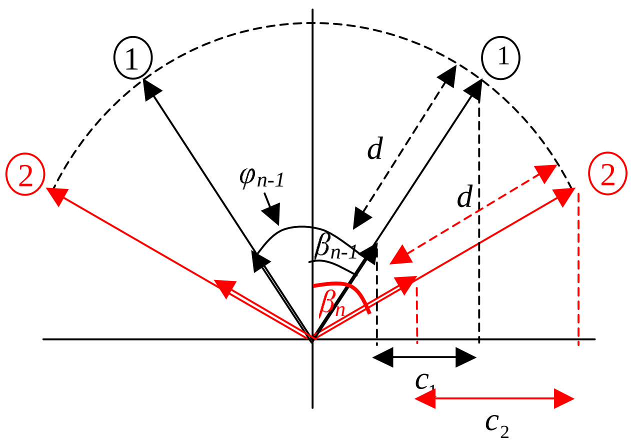

FIG. 1. The position of the magnetization vectors for the old, (1), and new, (2), RF pulses: (Case 1) The position of the magnetization vector after relaxation and before applying the new RF pulse. Due to relaxation, the transverse projection of the tagging contrast, c_1, gets smaller. (Case 2) The position of the vector using the new (larger) flip angle $\varphi_n=2\beta_n$,in order to keep constant tagging contrast. It is desired that with the larger flip angle, the new projection of the tagging contrast, c_2, compensates the previous decay.

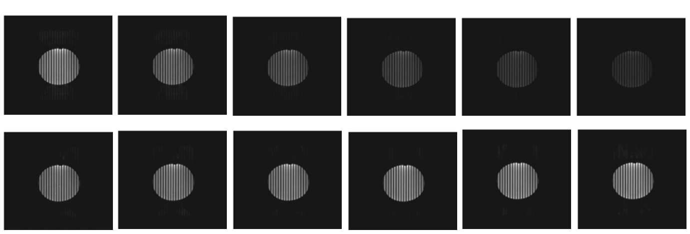

FIG. 2. Cine images of CSPAMM-tagged phantom throughout a 750 ms period of time (starting from left). The images in the top row are acquired with usual SSFP. In the second row, the ramped flip angles technique is used with SSFP.

CONCLUSIONS

A new method is proposed for improving TagCNR when imaging with SSFP. The previous figures show that the proposed method is capable of maintaining constant TagCNR throughout the whole cardiac cycle.

REFERENCES

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[3] Ibrahim, E., et al, *ISBI-IEEE*, 1051-1054, 2004.

ACKNOWLEDGMENTS

Grants: Donald W. Reynolds Foundation and NHLBI R01_HL072704.

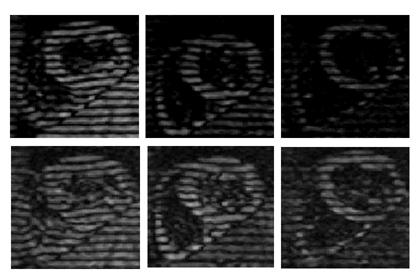

FIG. 3. Three short axis images of the heart at the beginning, middle, and end of the cardiac cycle. Top row shows the usual SSFP images and second row shows SSFP with ramped angles.

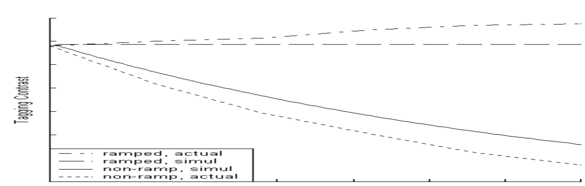

FIG. 4. TagCNR throughout all heart phases for the phantom experiment. Solid, dashed, dotted, dot-dashed lines represent non-ramped-angles simulated, ramped-angles simulated, non-ramped-angles actual, ramped-angles-actual, respectively.