Real-time Cardiac Fat Navigator Gated SSFP 3D Coronary MRA Using a Fast Kaiser Magnetization Preparation

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INTRODUCTION

Balanced SSFP imaging is an excellent choice for coronary MRA due to its short repetition time, high blood signal, and superior blood-to-myocardium contrast [1]. Recently the cardiac fat navigator has been developed to directly measure bulk cardiac motion [2]. The objective of this study is to demonstrate the feasibility of employing a cardiac fat navigator in SSFP 3D coronary MRA. To minimize the delay between the navigator echo and the imaging echoes, SSFP magnetization preparation can be executed before the navigator using a pair of α/2 pulses (Fig. 1a) [3]. This approach is not optimal for the cardiac fat navigator, because after the first α/2 pulse, the fat spins are aligned close to the transverse plane, limiting the amount of cardiac fat signal for motion tracking. Accordingly, it is highly desired to have a rapid magnetization preparation applied after the cardiac fat navigator echo and before the imaging echoes (Fig. 1b). We investigate methods to shorten the duration of the preparatory RF train by comparing three preparation techniques: α/2 [4], linear ramp with 20 RF pulses (20LR) [5], and Kaiser ramp with 6 RF pulses (6KR) [6].

MATERIALS AND METHODS

The three implemented magnetization preparations are shown in Fig. 2a-c. Note that an RF flip angle larger than 90° was used in the cardiac fat navigator to provide near maximum navigator signal and to suppress the epicardial fat. This eliminates the time delay (~20 ms) associated with a separate fat saturation pulse used in conventional approaches [1,3,5].

The three preparations were incorporated into an ECG-triggered navigator SSFP 3D coronary MRA pulse sequence (TR=4 ms, TE=1.2 ms, FA=60°, rBW=±62.5 kHz, 1.2x1.3x3.0 mm^3 resolution, 16 echoes per heartbeat, sequential view order along k_z). For navigator gating, the efficient PAWS gating algorithm [7] was implemented on a workstation that controlled data acquisition in real time.

Bloch simulation was performed to compare the cardiac fat signals available for motion tracking using an α/2 pair (Fig. 1a) and the proposed preparation (Fig. 1b), and to investigate the off-resonance behavior for the three implemented preparations.

Imaging experiments were then performed on a static phantom (consisting of water and oil bottles) and in healthy volunteers (n=11) using a 1.5T GE SIGNA CV/i MR system. The three preparations were performed in random order. Overall image quality difference was scored by two independent readers. A paired sample signed rank Wilcoxon test was performed on the consensus image score to determine the statistical significance.

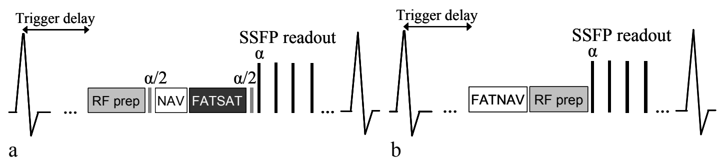

Fig.1. Imaging schematics of the ECG-triggered navigator gated SSFP coronary MRA in which the RF preparation is executed a) before and b) after the navigator.

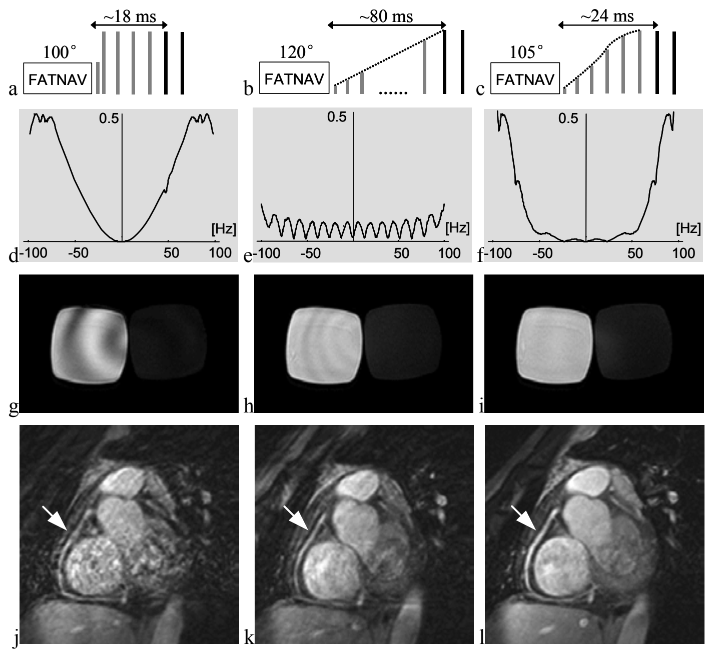

Fig.2. Three magnetization preparations for cardiac fat navigator SSFP coronary MRA: a) α/2 (+4 disdacqs), b) 20LR, c) and 6KR. Corresponding signal oscillation magnitudes (d-f), phantom images (g-i), and human images (j-l) are shown.

RESULTS

Simulation showed that the α/2 pair preparation (Fig. 1a) [3] provided only 29% of the maximum available cardiac fat signal for motion tracking. On the contrary, the α/2, 20LR and 6KR preparations (Fig. 2a-c) provided 98%, 87% and 97% of the maximum available signal. Simulation also showed that within a ±50 Hz off-resonance frequency range, the 6KR preparation provided the smoothest signal transition; the α/2 preparation always performed the worst (Fig. 2d-f). Phantom images showed signal oscillations that were substantial with the α/2 preparation, moderate with the 20LR preparation, and minimal with the 6KR preparation. All three preparations provided effective fat suppression. (Fig. 2g-i).

Human coronary MRA were obtained successfully from all subjects. The α/2 preparation demonstrated severe signal oscillations, particularly in slices near the volume edges (Fig. 2j). Moderate to severe motion artifacts were found using the 20LR preparation due to the long delay between navigator and imaging echoes (~80 ms) (Fig. 2k). Effective fat and motion suppression and the best image quality were obtained using the 6KR approach (Fig. 2l). Overall the 6KR preparation outperformed both the α/2 ($p<0.0025$) and the 20LR preparations ($p<0.025$). The difference between the α/2 and the 20LR preparations was not significant (p=0.2).

CONCLUSION Our preliminary data have demonstrated that 1) cardiac fat navigator gated SSFP 3D coronary MRA is feasible, 2) cardiac fat navigator provides reliable measurement of cardiac motion and effective fat suppression, and 3) the fast 6KR preparation provides more robust magnetization preparation than the α/2 preparation and more effective motion suppression than the 20LR preparation.

REFERENCES 1. Spuentrup E et al. Invest Radiol 2003;38:263-268. 2. Nguyen TD et al. MRM 2003;50:235-241. 3. Nguyen TD et al. MRM 2004;51:1297-1300. 4. Deimling M et al. ISMRM 1994. p 495. 5. Deshpande VS et al. MRM 2003;49:151-157. 6. Le Roux P. J Magn Reson 2003;163:23-37. 7. Jhooti P et al. MRM 2000;43:470-480.