Blood-myocardial contrast optimization in 3D True-FISP cardiac imaging at 1.5 T

P. Martirosian[1], M. Fenchel[2], G. F. Greil[3], U. Kramer[2], S. Miller[2], C. D. Claussen[2], F. Schick[1], L. Sieverding[3]

[1]Section on Experimental Radiology, University of Tübingen, Tübingen, Germany, [2]Department of Diagnostic Radiology, University of Tübingen, Tübingen, Germany, [3]Department of Pediatric Cardiology, University of Tübingen, Tübingen, Germany

Synopsis

With the advent of steady-state free precession imaging techniques, 3D true-FISP sequences can image both intra- and extra-cardiac morphology. Contrast behaviour of 3D True-FISP sequences was optimized in numerical simulations, and studies were performed in healthy volunteers. All in vivo studies were performed on a 1.5 T scanner. Two steady state preparation schemes in combination with a T2 preparation prepulse were compared in order to improve contrast between blood and myocardium using a navigator gated and ECG-triggered 3D True-FISP sequence. Numerical simulations and experimental studies in volunteers showed that the steady state preparation by constant flip angle is preferable to linear flip angle preparation, concerning the contrast between blood and myocardium. The optimized 3D True-FISP sequence provides reliable, accurate and time efficient morphologic cardiac diagnosis.

Introduction

Cardiac MRI has become a clinically useful addition to echocardiography in the diagnosis and follow-up of patients with heart disease. The widespread use of MRI in cardiac, however, is hampered by complex nature of the multiple 2D MR scanning protocols and the need for highly individualized planning procedures. With the advent of steady-state free precession imaging techniques, 3D true-FISP sequences can image both intra- and extra-cardiac morphology. A disadvantage of 3D versus 2D True-FISP sequences is lower contrast between blood and myocardium. To overcome this problem, the T2 preparation prepulse was suggested (1), which has been demonstrated to enhance in 2D MRA applications (2). For reduction of signal oscillations in True-FISP sequences, generally a steady state preparation was needed. The purpose of this work was to assess the steady state preparation method of a $\alpha/2$ pulse (α is data acquisition RF-pulse flip angle) followed by constant flip angle preparation cycles (CFA) (3, 4), with regard to blood-myocardial contrast. The CFA preparation was compared to linear flip angle preparation scheme (LFA) (5). Numerical simulations and studies in healthy volunteers were performed.

Methods

In vivo studies in eight healthy volunteers were performed on a 1.5 T scanner (Siemens Medical Solutions, Erlangen, Germany). A T2 preparation prepulse (2) was implemented in a 3D navigator gated true-FISP sequence with parameters: TE=1.7-2.1 ms, α=60-110°, TE_{T2prep}=48 ms. Voxel size was between 1.5×1.5×1.5 and 2.0×2.0×2.0 mm^3. Additionally, two steady state preparation schemes CFA (4) and LFA (5) with twenty preparartion cycles were implemented. The data acquisition time per heartbeat was adjusted to the heart rate of the volunteer, using an appropriate number of segments. The centric reordered phase encoding scheme was used to be sensitive to the prepared magnetization. For simultaneous gating, navigator technique was applied. The 3D scan was triggered to end diastole. The transverse magnetization of True-FISP experiments was simulated as function of the number of RF excitations and the flip angle for CFA and LFA steady state preparation schemes (6). The simulation was performed for the following parameters: TE/TR=2.0/4.0 ms; RR-interval=800 ms; flip angle 65°, 90°, 110°; number of preparation RF pulses 20; TE_{T2prep}=48 ms. T1 and T2 for blood and myocardium were assumed to: $T1_b/T2_b$=1200/250 ms and $T1_m/T2_m$=900/70 ms. The relative blood-myocardial contrast (defined as $(S_b-S_m)/S_m$, S_b and S_m are the signal intensities of blood and myocardium) was calculted for simulation and measurement studies.

Results

Numerical simulations showed that using the CFA preparation the relative contrast between blood and myocardium is higher than using LFA preparation (Fig. 1). Furthermore, with CFA preparation an increase of the flip angle from 65° to 110° (Fig. 1a) resulted in a relative contrast increase by a factor of approx. 1.37, whereas using LFA preparation (Fig. 1b) it only increases by a factor of approx. 1.11. For the flip angles 65°, 90° and 110° contrast ratios (CFA/LFA) of approx. 1.25, 1.40 and 1.54 were calculated, respectively.

Images of an adult volunteer acquired with the T2 prepared 3D True-FISP sequence using CFA and LFA preparation schemes at flip angle of 65°, 90°, and 110° are shown in Fig. 2. By increasing the flip angle from 65 to 110°, the relative contrast in images with CFA preparation (Fig. 2a,c) increased by 1.42 and, in contrast, with LFA preparation (Fig. 2d,f) by 1.15. The contrast ratios (CFA/LFA) of approx. 1.15, 1.25 and 1.40 can be calculated for flip angle of 65°, 90° and 110°, respectively.

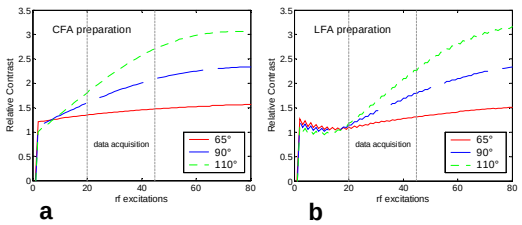

Fig.1: Numerical simulations of the relative contrast between blood and myocardium of True-FISP experiment using CFA (a) and LFA (b) steady state preparation schemes for excitation flip angle of 65° 90° and 110°. Other simulation parameters are: TE/TR=2.0/4.0 ms, RR-time=800 ms, number of preparation RF pulses 20, TE_{T2prep}=48 ms

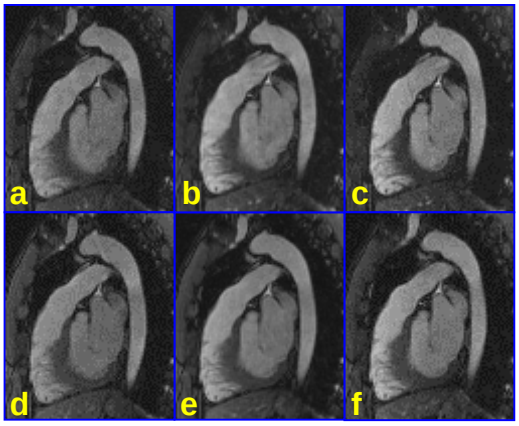

Fig. 2: Images of a healthy volunteer acquired by T2 prepared 3D True-FISP with CFA (a,b,c) and LFA (d,e,f) steady state preparation schemes for flip angles 65°, 90° and 110°.
Sequence parameters are:
TE/TR = 1.9/3.8 ms
Segments = 25
TE_{T2prep} = 48 ms
Voxel-size = 2×2×2 mm^3

Discussion

Although 3D True-FISP already proved useful for standardized and time efficient morphologic cardiac assessment, increasing the contrast of blood and myocardium is necessary for high diagnostic accuracy. Numerical simulations and experimental data showed very high correlation. T2 preparation leads to increased contrast between blood and myocardium. Steady state preparation by constant flip angle is preferable to linear flip angle preparation due to higher blood/ myocardial contrast at identical flip angles. Furthermore, contrast ratios (CFA/LFA) increase with larger flip angles.

References

1. Botnar RM, et al. Circulation 1999; 99: 3139-3148.
2. Brittain JH, et al. Magn Reson Med 1995; 33: 689-696.
3. Deshpande VS, et al. Magn Reson Med 2001; 46: 494-502.
4. Deimling M, Heid O. In: Proceedings of ISMRM 1994, p. 495.
5. Nishimura DG, Vasanawala S. In: Proceedings of ISMRM 2000, p. 301.
6. Freeman R, Hill HDW, JMR 1971; 4:366-383.