Single Breath Hold 3D Cine Cardiac Imaging using Spiral SSFP

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INTRODUCTION

2D cine imaging is routinely used for visualization of cardiac motion, but suffers from slice misalignment when data are acquired across multiple inconsistent breath holds. This misalignment can cause difficulty in 3D reformatting and quantification of ejection fraction [1]. It is highly desirable to have a 3D cine study within a single breath hold that offers properly registered slices and coverage of the entire ventricular volume. Several previous attempts at 3D cine imaging used rectilinear or radial trajectories [1][2], which limit the amount of data sampling per echo. Here we use a fast spiral trajectory to develop a breath hold cine SSFP sequence.

METHODS

A spiral SSFP pulse sequence (Fig 1) was developed using a variable density 3D stack of spirals trajectory [3][4] that oversampled the center of k-space but undersampled the periphery. 8 out of 14 z phase encodes were acquired to obtain a larger number of slices within a reasonable breath hold.

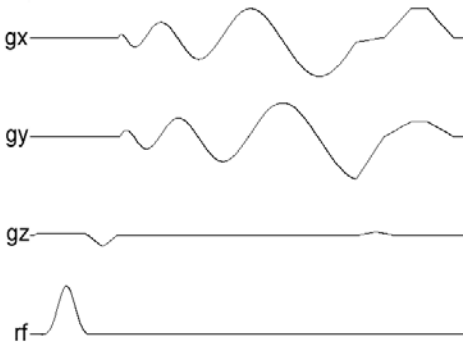

Fig 1. Spiral SSFP pulse sequence

Acquisition of each z phase encode was completed over 3 heart beats, sampling leaves numbered 3n in the first heartbeat, leaves numbered 3n+1 in the second heartbeat, and leaves numbered 3n+2 in the third heartbeat, for n integer. A sliding window reconstruction was performed to produce images from 16 cardiac phases. Each heartbeat was divided into 16 evenly spaced overlapping sets for the sliding window, and corresponding sets from each heartbeat were combined to produce the k-space data for each cardiac phase. The ordering of z phase encode acquisition and sliding window data grouping is illustrated in Fig 2. Homodyne processing with 5 iterations was performed to reduce slice blurring artifacts [5].

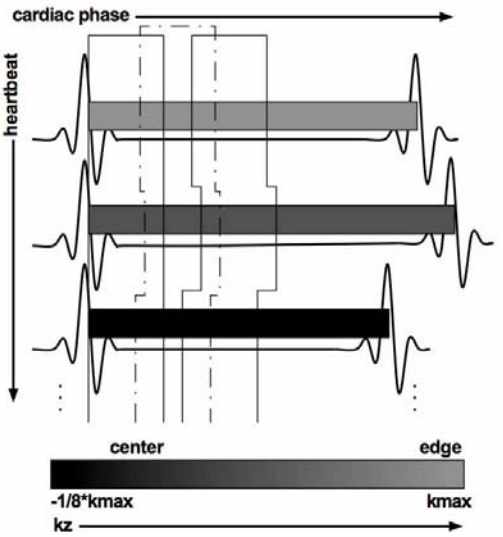

Fig 2. Sliding window reconstruction and distribution of k-space acquisition across heartbeats.

Scans were performed on a GE Excite 11 1.5T scanner using a 4 channel cardiac coil, 26cm FOV, 10mm slice thickness, 192x192 matrix, a maximum gradient strength of 33mT/m, and a maximum slew rate of 120T/m/sec. Sequence parameters were TR/TE/flip: 4.9-5.2ms/0.8ms/45°, 250kHz RBW, 48 spiral leaves, 16 leaves per heartbeat, 2.5ms readout. All breath holds lasted for 25 heartbeats, one heartbeat to achieve steady state, and 24 heartbeats for acquisition of the 8 z phase encodes. Peripheral finger gating was used to monitor the heartbeat.

RESULTS

Short axis cine scans were performed on 6 healthy volunteers. In all exams, short axis images with good contrast throughout the cardiac cycle were successfully obtained. Fig 3 shows short axis views throughout the cardiac cycle at two positions in the heart, one mid-ventricle, and one near the apex. Image contrast is adequate throughout the 10 inner most slices, enabling coverage of the ventricular volume in a single scan.

DISCUSSION

This work demonstrates the feasibility of performing 3D short axis cine imaging of the heart in a single breath hold using a balanced SSFP spiral trajectory. Our future work will focus on incorporation of parallel imaging and temporal prior based acceleration techniques to speed up data acquisition, allowing for shorter breath holds and thinner slices while still achieving coverage of the entire ventricular volume.

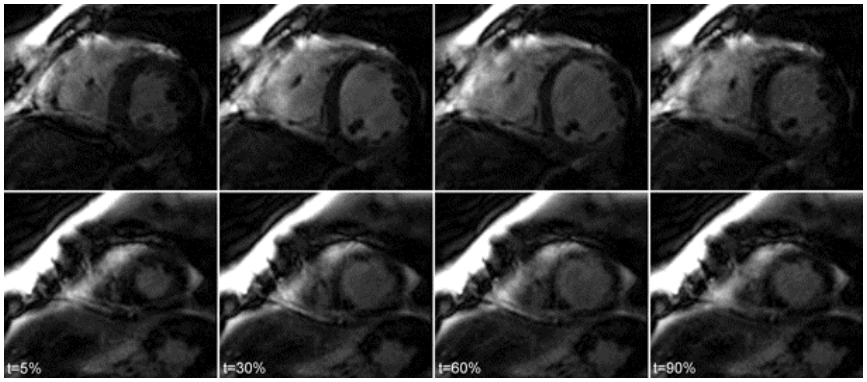

Fig 3. Two short axis views throughout the cardiac cycle. Times are shown as a percentage of time from one trigger to the next.

REFERENCES

[1] Barger AV, et al. MRM: 44:821-824, 2000. [2] Jung BA, et al. MRM: 48:921-925, 2002. [3] Hargreaves BA. Ph.D. Thesis, Stanford University, 2001. [4] Liao J, et al. MRM: 37:569-575, 1997. [5] Cuppen J. US Patent 485635, 1989.