FIESTA-SP: High-Temporal-Resolution 2D Cine MR Imaging of the Entire Heart in a Single Breath-Hold

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Introduction

For functional cine imaging of the heart using steady-state free precession (SSFP, FIESTA, TrueFISP), 10-12 slices are often imaged, each requiring a 12- to 16-sec breath-hold. While repeated breath-holding can be time consuming and exhausting for the patient, it also increases the likelihood of slice misregistration, which can negatively impact quantitative ventricular volume measurements. Accordingly, recent work has been directed at reducing the acquisition time to a single breath-hold for covering the entire heart. Although 3D sequences [1-3] have been investigated more often than 2D [4], both approaches have been subject to long breath-holds and low spatial and/or temporal resolution. The typical advantages of 3D acquisitions (i.e., higher SNR and thinner slices) are less relevant because SSFP imaging already offers high SNR, and the use of thin slices would make the requisite number of slices prohibitive. The disadvantages of 3D include the need to discard several slices from the ends of the slab due to aliasing and the effect on the whole slab of any motion during the entire breath-hold time. These problems are not present with 2D scans; however, multi-slice 2D imaging requires setting each slice to steady state individually (often with 1 or 2 dummy heartbeats) prior to data acquisition. This significantly reduces efficiency for data acquisition times less than about 4 heartbeats per slice (e.g., Ref. [4]). The purpose of this work was to develop an efficient multi-slice 2D SSFP technique that allows cine imaging of the entire heart in a single breath-hold. The **S**teady-State-**P**repared FIESTA (FIESTA-SP) method described here requires no dummy heartbeats or discarded slices, offers better immunity to motion than 3D, and provides improved spatiotemporal resolution.

Methods

In conventional multi-slice 2D imaging, dummy heartbeats are typically used prior to acquiring each slice. With the FIESTA-SP sequence, these dummy heartbeats are replaced with a more efficient approach to steady state, allowing data to be collected during every heartbeat of the breath-hold. As shown in Figure 1, during acquisition of the final (*N*th) cardiac phase of one slice, detection of an ECG trigger initiates a steady-state preparation for the next slice. The preparation consists of an $\alpha/2$ - TR/2 excitation [5] followed by a number of dummy TRs equal to the prescribed views per segment. Thus, no data is acquired during the first cardiac phase of the first heartbeat for each slice. After this preparation, data is collected in the usual manner for the remainder of the acquisition of the current slice. During the first heartbeat, data for the outer portions of k-space is acquired, except for the missing lines of the first cardiac phase. During the second heartbeat, data for the center of k-space, which at this point is much closer to steady state, is acquired for all cardiac phases. This acquisition order helps eliminate artifacts due to imaging during the transient state.

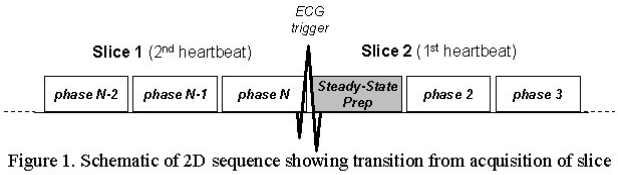

Figure 1. Schematic of 2D sequence showing transition from acquisition of slice 1 to slice 2.

Short-axis FIESTA-SP imaging of the heart was performed on 3 volunteers and 2 patients using a 1.5 T Signa CV/i scanner (GE Medical Systems, Milwaukee, WI) and a 4-element phased array cardiac coil. Imaging parameters were: TR/TE 3.8/1.6 msec; 45º flip angle; 250 kHz bandwidth; ½ NEX; 256 x 134 matrix; 36 cm FOV; 18 views per segment (VPS); contiguous 8 mm slices; parallel imaging (ASSET) factor of 1.67; 36 total acquired lines. Each slice required 2 heartbeats for data acquisition. Images were reconstructed using retrospective interpolation (FastCINE) [6].

Results

Figure 2 shows systolic and diastolic images of 8 of the 10 slices acquired from a patient scan. Images from all subjects exhibited consistently good image quality. The spatial resolution of 1.4 x 2.7 mm and true temporal resolution of 68 msec allowed clear depiction of cardiac function.

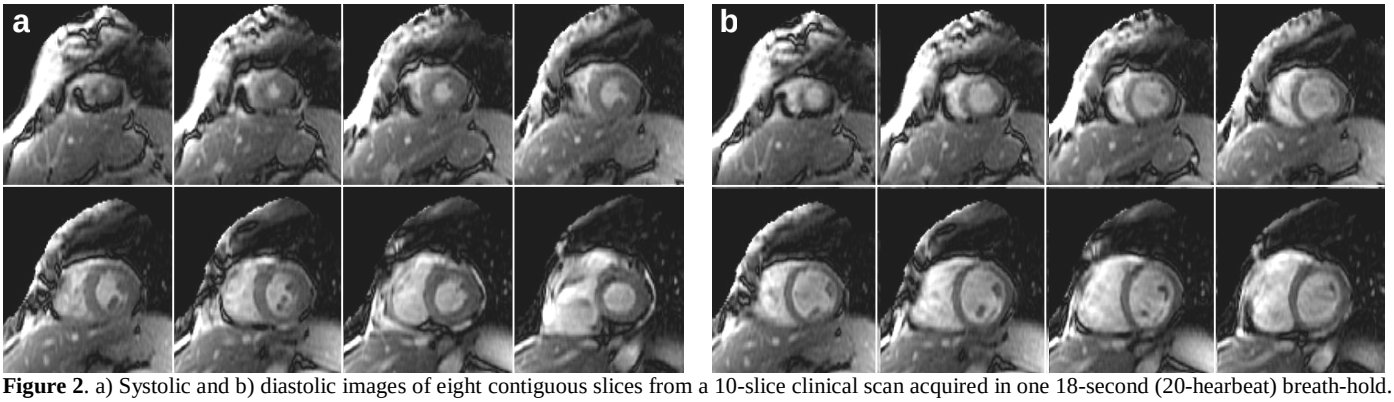

Figure 2. a) Systolic and b) diastolic images of eight contiguous slices from a 10-slice clinical scan acquired in one 18-second (20-hearbeat) breath-hold.

Discussion and Conclusion

This work has demonstrated the feasibility of FIESTA-SP for high-temporal-resolution cine imaging of the entire heart in a single breath-hold. With data acquisition requiring only 2 heartbeats per slice, complete coverage of the heart can be achieved in 16-24 heartbeats, depending on the clinical situation. 2D imaging has several advantages over 3D, including flexibility of prescription (e.g., custom slice ordering and (multi-planar) orientation) and greater robustness to poor breath-holding. In the latter case, an entire 3D slab could be corrupted if a breath-hold ended prematurely. In contrast, the slices acquired early in a 2D scan would be unaffected, while the later slices, due to the very short data acquisition period, could potentially be imaged successfully during free breathing.

References

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