

Segmented TrueFISP Cine Imaging of the Heart

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Purpose

The purpose of this study was to develop a segmented TrueFISP¹ pulse sequence for cine imaging of the heart with short TR while maintaining high blood/myocardium contrast. Short TR can be used to achieve shorter breath-holds, or higher temporal or spatial resolution than possible with standard segmented FLASH techniques.

Introduction

Breath-hold cine imaging of the heart is widely used to evaluate cardiac function by MRI. The temporal and spatial resolution of this technique are limited by the total acquisition time which must be within a comfortable breath-hold (15 – 20 heartbeats). Spoiled gradient echo sequences which rely on inflow enhancement for blood/myocardium contrast are typically used. As gradient performance improves, the minimum TR attainable in such a sequence decreases. However, inflow enhancement is diminished at shorter TR's causing saturation of the blood signal and reduction of blood/myocardium contrast. At very short TR, it may be advantageous to exploit the difference in blood and myocardium relaxation times rather than rely on inflow enhancement. Blood has a significantly lower T1/T2 ratio than myocardium. At very short TR, TrueFISP is sensitive to T1/T2 and potentially offers higher contrast-to-noise than FLASH as well as inherent motion insensitivity².

For these reasons, TrueFISP has been utilized for real-time cardiac fluoroscopy^{3,4}, but at relatively low temporal and spatial resolution. In this work, we apply the TrueFISP technique in a segmented k-space, breath-hold acquisition, taking advantage of the short TR and inherently high contrast between blood and myocardium to achieve faster scan times than standard FLASH techniques.

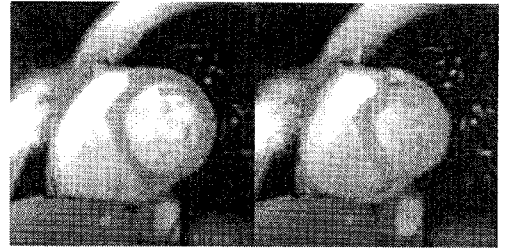
Methods

The segmented True FISP sequence was implemented on a 1.5T Magnetom Sonata (Siemens Medical Systems, Iselin NJ) with a high performance gradient system (40 mT/m amplitude, 200 T/m/sec slew rate). The sequence is based on a breath-hold, ECG-triggered, segmented k-space acquisition with echo-sharing⁵ to improve temporal resolution. The basic TrueFISP timing module used has TR=4.0 ms and TE=2.0ms. Pulse sequences with 11, 15, and 19 lines per segment and corresponding temporal resolution of 24, 32, and 40 msec were implemented. To achieve and maintain the steady state required by TrueFISP, RF and gradient pulsing are applied for one preparatory heartbeat and then constantly applied without interruption throughout the entire acquisition. Typical imaging parameters for the 19 line per segment sequence are 133 x 256 pixels with dimensions of 2.0mm x 1.25mm x 6 mm slice thickness acquired in 7 heartbeats. The flip angle (α) was 50° and receiver bandwidth was 780 Hz/pixel. This sequence was compared to a segmented FLASH with TR 8.0 msec, TE 4.0 msec, $\alpha = 20^\circ$, and 230 Hz/pixel bandwidth. A CP 4-channel phased array body coil was used.

Results

Image examples of short-axis and 4-chamber views obtained in a volunteer are shown in Figures 1 and 2.

FLASH
TR = 8 msec



TrueFISP
TR = 4 msec



Figure 1. Two time frames (left = end-diastole, right = end-systole) comparing segmented FLASH (top) and segmented TrueFISP (bottom). Contrast between the blood and the myocardium is maintained at shorter TR using the TrueFISP acquisition. Acquisition time for FLASH images was 20 seconds compared to 10 seconds for TrueFISP. Temporal resolution (40 msec) and spatial resolution are equivalent.

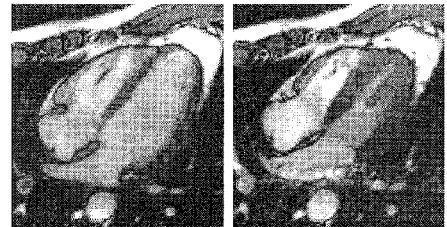


Figure 2. Two time frames (left = end-diastole, right = end-systole) from segmented TrueFISP cine with TR 4.0 msec showing high blood/myocardium contrast in 4-chamber view.

Discussion

The standard FLASH cine sequence has a TR of 8 msec not due to gradient limitations, but to maintain sufficient inflow enhancement. TrueFISP cine demonstrated equivalent blood myocardium contrast throughout the cardiac cycle at half the TR of FLASH. This factor of two time savings can be used to shorten the breath-hold as shown in the example, or to increase either spatial or temporal resolution in the same breath-hold period. The reduced reliance on inflow enhancement of TrueFISP is also advantageous in long-axis orientations which often suffer from saturation of blood signal in FLASH. TrueFISP is sensitive at high field to B_0 inhomogeneity, but this problem is reduced at the short TR's possible with high performance gradient hardware.

True FISP allows us to take advantage of short TR imaging without sacrificing blood/myocardium contrast.

References

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