Reducing the TR in SSFP Imaging with Ramp-Sampled FIESTA

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Introduction

Fast gradient-recalled echo (GRE) imaging is often the pulse sequence of choice when imaging moving objects and when short acquisition times are desirable. Reducing the repetition time (TR) can allow shorter scan times, increased spatial and/or temporal resolution, and fewer motion-related artifacts. If the TR is too short, however, signal-to-noise ratio (SNR) and image quality suffer. Balanced steady-state free precession (SSFP) imaging provides very high SNR using very short TRs. With SSFP, it is often desirable to minimize the TR, because longer TRs can result in image artifacts due to off-resonance effects. As opposed to GRE, in most cases using SSFP, the shortest possible TRs often provide the best image quality.

The purpose of this work was to reduce the TR of a spin-warp SSFP (FIESTA) imaging sequence by employing ramp sampling during data acquisition. Ramp sampling involves data sampling and collection during the attack and decay ramps of the readout pulse. It is often used for pulse sequences that use oscillating gradient waveforms (and consequently a large number of ramps), such as echo-planar imaging. It is not used for, and would typically not be beneficial for, conventional GRE imaging. For GRE, the receiver bandwidth is usually a factor of four lower than for SSFP. This means that the readout pulse amplitude is four times lower, and lower amplitudes require shorter ramps. For a standard double-oblique cardiac cine acquisition using GRE (with a typical of TR of 6-7 ms), there is only about 50-60 µs of ramp time available for sampling. This would yield a negligible reduction in TR. Furthermore, with GRE, the decay ramp is typically bridged to a frequency-encoding spoiler pulse or overlapped by phase-encoding rewinder and slice-select spoiler pulses (Fig. 1). As such, the decay ramp is in fact unavailable for ramp sampling.

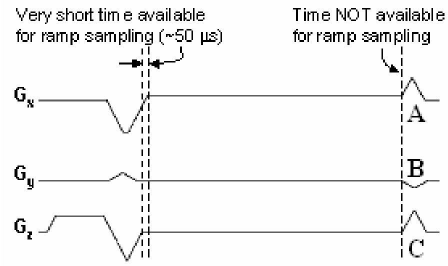

Figure 1. GRE pulse sequence. A=frequency-encoding spoiler pulse; B=phase-encoding rewinder pulse; C=slice-select spoiler pulse.

On the other hand, the longer ramps in SSFP are much more amenable to ramp sampling. In addition, there is a frequency-encoding rewinder pulse after the readout decay ramp; if the phase-encoding rewinder and the slice-select prephaser pulses are positioned to overlap this pulse, the relatively long readout decay ramp becomes available for ramp sampling (Fig. 2). For a typical TR of 3-4 ms, each ramp is almost 200 µs in duration, and because both ramps are usable, there is approximately 400 µs available for sampling.

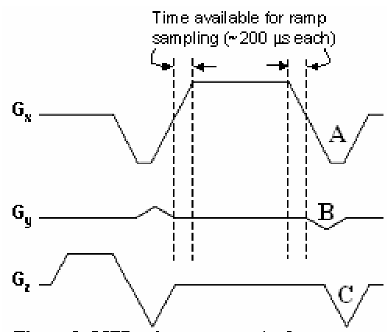

Figure 2. SSFP pulse sequence. A=frequency-encoding rewinder pulse; B=phase-encoding rewinder pulse; C=slice-select prephaser pulse.

Methods

Short-axis cardiac cine scans were performed on four volunteers on a 1.5T GE CV/i scanner using a FIESTA pulse sequence with and without ramp sampling. Imaging parameters were: 45° flip angle, 256x168 matrix, 35x28 cm FOV, 7 mm slice thickness, 16 VPS. Typical TRs were 3.82 ms for standard FIESTA and 3.48 ms for ramp-sampled FIESTA.

Results

Figure 3 shows images of corresponding phases from the ramp-sampled (left) and standard FIESTA (right) scans. As expected, the images exhibit essentially identical image quality.

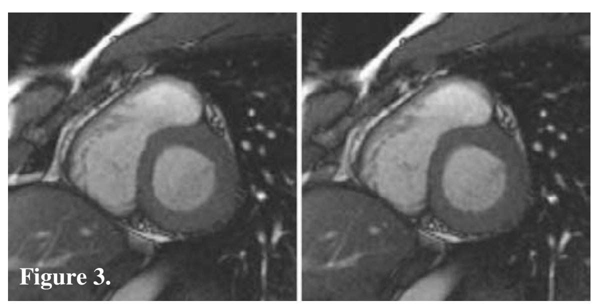

Figure 3.

Discussion and Conclusions

This work has demonstrated that employing ramp sampling in an SSFP pulse sequence can reduce the TR by approximately 10% without affecting image quality. This reduction of TR can be important for reducing artifacts due to off-resonance effects. When used in segmented acquisitions, the shorter TR enables higher temporal resolution, because the duration of each segment is proportionally shortened. For 3D cardiac imaging, this proportionate reduction can significantly decrease the duration of data acquisition, which can lessen the effects of cardiac motion. Shortened TRs may be particularly valuable for imaging on high field (e.g., 3T) systems, because the deleterious effects of off-resonance conditions are even more pronounced. Acquisitions using smaller FOVs will see higher percentage reductions in TR, because the higher readout gradient amplitudes require more ramp time.