Partial Fourier Steady-State Free Precession (FIESTA) First-pass Perfusion with Improved Image Quality and Efficient Spatial Coverage

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Introduction

The use of steady-state free precession (SSFP) for first-pass imaging of myocardial perfusion was first proposed by Schreiber, et al. [1]. However, that implementation was limited by inadequate ventricular coverage (270 ms acquisition time). This work described herein proposes the use of partial Fourier acquisition to obtain relatively high temporal resolution first-pass perfusion images, with greater spatial coverage of the heart. First-pass perfusion images using both the proposed saturation-recovery SSFP or FIESTA acquisition and an interleaved segmented EPI (FGRET) [2] acquisition sequences were compared for contrast-enhancement ratios (CER). The CER provides an indication of the maximal possible contrast between an ischemic zone and normal enhancing myocardial tissue.

Materials and Methods

The acquisition (SR-FIESTA) was a SSFP or FIESTA sequence with a non-selective saturation-recovery preparation pulse for magnetization preparation. The imaging parameters were: TR/TE = 2.9/1.1 ms; 40-degree flip angle, 128 x 96 acquisition matrix; 36-40 cm FOV (28 cm in the dog studies); 8 mm section thickness; 0.5 NEX (partial Fourier acquisition) and a phaseFOV factor of 0.75. The acquisition was preceded by an alpha/2-TR/2 preparation and 5 dummy rf excitation pulses. This resulted in an acquisition time of 205 ms and an effective TI of 142 ms. These parameters compared with the standard FGRET sequence (128 x 128; ETL=4) that had an acquisition time of 168 ms and a TI of 186 ms. Forty phases were acquired with each phase or time-point representing 2 RR intervals. In all cases, both the FGRET and SR-FIESTA acquired between 7-10 slice locations, with SR-FIESTA sometimes acquiring 1 less slice location due to the slightly longer acquisition time.

Twenty-six patients (18 male and 8 female; mean age: 58 +/- 15 years; mean weight: 85 +/- 18 kg) who were referred for an MR viability assessment were enrolled in the study. Of these patients, 11 received a first-pass SR-FIESTA study with 0.05 mmol/kg dose of Gd contrast media, 15 patients had a first-pass FGRET study with 0.1 mmol/kg dose (n=12) and 0.05 mmol/kg dose (n=3) of Gd contrast media. All perfusion studies were conducted at rest. In addition, two anaesthetized dogs with reperfused myocardial infarctions were also studied with 0.05 mmol/kg Gd contrast media with SR-FIESTA and FGRET on separate days. For all patients, the baseline and peak myocardial signal intensity in either the anterior septal or anterior lateral wall were measured. Normal myocardial tissue, as determined from the viability (delayed enhancement) study was used. The contrast enhancement ratios (peak – baseline / baseline) for myocardial tissue as well as ventricular blood were calculated from the measurements.

Results

In comparing the SR-FIESTA at 0.05 mmol/kg with the FGRET patients at 0.1 mmol/kg, the myocardial CER for SR-FIESTA was 1.9 +/ 0.6 compared with 2.2 +/- 0.8 for FGRET ($p = 0.42$). This indicated that there was no significant difference between SR-FIESTA at the lower contrast dose than the FGRET acquisition at the higher 0.1 mmol/kg dose. At 0.05 mmol/kg, myocardial CER with FGRET at rest was 0.9 +/- 0.4 ($p<0.01$, compared with 0.05 mmol/kg SR-FIESTA), indicating that there was statistically significant improvement in CER with SR-FIESTA at the same dose. Figure 1 shows the improved image S/N and conspicuity of the perfusion deficit in an animal model. Fig. 2 shows the ability to visualize regions of perfusion deficit in a patient despite the use of a 0.05 mmol/kg dose following a 0.1 mmol/kg of dose FGRET experiment. In all images, the SR-FIESTA images demonstrated an improved image S/N.The mean noise over all subjects was 2.3 for SR-FIESTA and 4.9 for FGRET ($p < 0.001$). This indicated that the overall contrast-to-noise ratio (measured as a CER/σ) was better with SR-FIESTA than with FGRET.

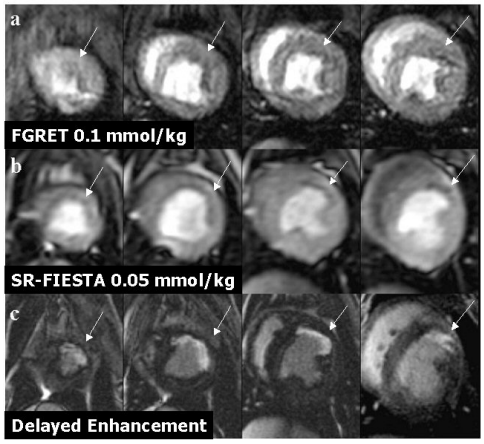

Fig.1: (a) FGRET perfusion with 0.1 mmol/kg Gd contrast (b) 0.05 mmol/kg SR-FIESTA perfusion and (c) delayed enhancement images showing regions of MI. The perfusion scans were conducted on separate days. Note the improved conspicuity of the perfusion deficit zone (arrows) and S/N in the SR-FIESTA perfusion images (b). The perfusion deficits correspond to the no reflow zones within the infarcted regions in (c).

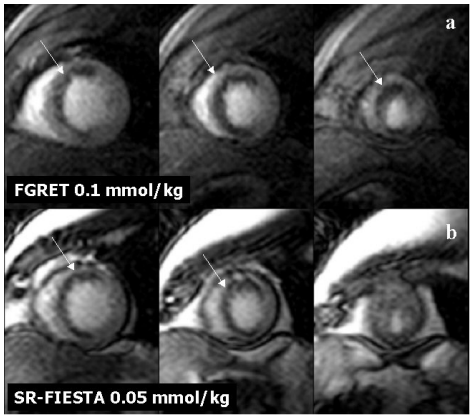

Fig. 2: (a) FGRET images with 0.1 mmol/kg Gd and (b) SR-FIESTA images with 0.05 mmol/kg Gd in a 44-year-old male patient with acute myocardial infarction. The SR-FIESTA perfusion scan was performed immediately after the FGRET perfusion acquisition. Note the pronounced no-reflow zone observed with both FGRET and SR-FIESTA (arrows). Only three slices of a 8 slice acquisition are shown in this patient with a heart rate of 83 bpm.

Conclusions

We have demonstrated that the SR-FIESTA perfusion sequence using partial Fourier techniques was able to provide comparable spatial coverage as with the standard interleaved EPI (FGRET) acquisition. Moreover, the CER for SR-FIESTA at a 0.05 mmol/kg dose was comparable to that of FGRET at 0.10 mmol/kg, with an improvement by a factor of 2 at the same contrast dose as FGRET. This provides an opportunity to improve qualitative assessment of first-pass perfusion at a reduced contrast dose without sacrificing left-ventricular coverage.

References

1. Schreiber WG, et al. *J Magn Reson Imag* 2002; **16**: 641-52.
2. Slavin GS, et al. *Radiology* 2001; **219**: 258-63.