High Spatial Resolution Optimization of SSFP TruFISP Myocardial Perfusion MRI and Comparison with Spoiled Gradient Echo

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Introduction:

First-pass imaging of myocardial perfusion has emerged as a noninvasive method that allows accurate assessment of myocardial blood flow. However, this technology has been utilized with only limited spatial resolution (~2.8 mm in-plane resolution). Higher spatial resolution is desirable for accurate interpretation and quantitative analysis. We hypothesized that the higher SNR of saturation recovery SSFP [1-5] combined with an acquisition scheme designed to minimize cardiac motion could be used to obtain improved spatial resolution (1.9 mm in-plane resolution) with similar contrast and frequency of artifacts as spoiled gradient echo.

Methods:

Imaging was performed on a 1.5T Siemens Avanto scanner using a SSFP sequence with a non-selective saturation-recovery preparation pulse. Signal characteristics and flip angle were first optimized based on phantom experiments to determine the signal response to varying doses of gadolinium concentration in order to establish a range of concentrations over which the signal response was linear (Figure 1). The imaging parameters were: TR/TE/TI = 2.5/1.1/180 ms; 40-degree flip angle; 192 x 154 acquisition matrix; 36-40cm FOV; 8 mm section thickness; phase FOV 0.75; GRAPPA factor of 2 with 21reference lines. This resulted in a data acquisition time per image of 170 ms. In order to reduce artifacts produced by myocardial contraction, trigger time was adjusted according to the heart rate so that image acquisition windows during the cardiac cycle were set on myocardial quiescent periods (end-systole and mid-diastole). Thus, 4 slices were acquired per every 2 RR intervals. These parameters were compared with the spoiled gradient echo (TurboFLASH) sequence (12-degree flip angle; 128 x 128 acquisition matrix; 36-40 FOV; 8mm thickness) employing a GRAPPA factor of 2 (reference lines 21) with data acquisition time per image of 168 ms. All perfusion studies were conducted at rest. The baseline and peak myocardial signal intensity were measured in normal myocardial tissue, as determined from a delayed enhancement study. The noise-normalized contrast enhancement (peak – baseline / noise) (NNCE) for normal myocardial tissue were calculated. A subtraction was performed between two images before contrast arrival in order to estimate noise. Noise was defined as standard deviation of the signal measured in the region of interest placed on the normal myocardial tissue on the subtraction image. Subendocardial hypointensity artifacts were evaluated in each coronary artery territory by using a 3-point scale; 0: no artifact, 1: minimal, 2: artifacts interfering with diagnostic image quality. Analysis of covariance was used to compare the NNCE while removing the obscuring effect of body weight difference in the two groups.

Results:

A total of 120 coronary artery territories in 40 patients (28 male and 12 female; mean age: 59 +/- 11 years) were evaluated in the study. Twenty patients (13 male and 7 female; mean age: 59 +/- 12 years; mean weight: 77 +/- 15 kg) received a first-pass study with TurboFLASH using 0.1 mmol/kg Gd-DTPA-BMA. Another 20 patients (15 male and 5 female; mean age: 59 +/- 9 years; mean weight: 92 +/-20 kg) underwent a first-pass study using the high-resolution SSFP sequence (Figure 2). Contrast dose of 0.05 mmol/kg was used for SSFP based on the literature as well as phantom optimization studies [2-5]. Comparing the high-resolution SSFP at 0.05 mmol/kg with the TurboFLASH at 0.1 mmol/kg, the myocardial NNCE for SSFP was 7.5 +/- 2.0 compared with 8.7 +/- 2.1 for TurboFLASH (p=n.s.). Grade1 and 2 artifact was found in 18 and 3 territories with SSFP, 18 and 4 territories with TurboFLASH. Overall frequency and severity of subendocardial hypointensity artifacts were similar between the two methods.

Conclusion:

Our results indicate that myocardial perfusion MRI with less than 2 mm inplane resolution can be obtained using saturation recovery SSFP with comparable noise-normalized contrast- enhancement as saturation recovery TurboFLASH. In addition, SSFP and TurboFLASH showed similar frequency and severity of subendocardial artifacts although these artifacts were more problematic with SSFP than TurboFLASH in previous reports [1,3,5]. High spatial-resolution SSFP perfusion MRI can be a robust alternative to TurboFLASH for the detection and quantification of myocardial perfusion abnormalities.

Figure 1 Signal vs Gd-concentration relationship in SSFP perfusion with flip angle of 40 degrees and inversion time of 180ms evaluated in test tubes of different concentration of Gd-DTPA-BMA. Linear relationship was observed up to 1mM.

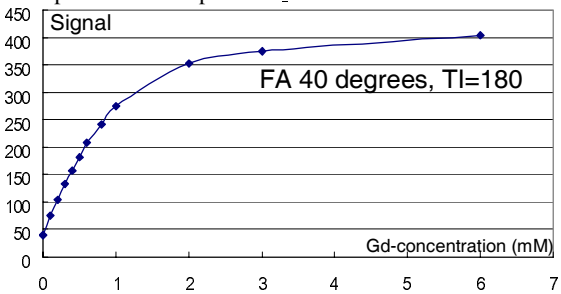
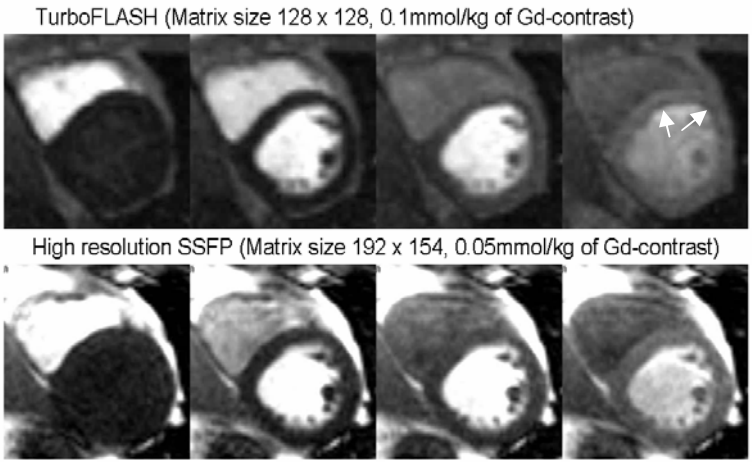


Figure 2 TurboFLASH and high-resolution SSFP first-pass perfusion images obtained from a patient. Myocardial contour is sharper with SSFP than TurboFLASH due to improved spatial resolution. No subendocardial artifact was seen on SSFP in this patient, while minimal artifact was noticed on turboFLASH(arrows).



References:

[1] Schreiber WH, et al. J Magn Reson Imaging. 2002;16:641-652.
[2] Hunold P, et al. Eur Radiol. 2004;14:409-16.
[3] Fenchel M, et al. J Magn Reson Imaging. 2004;19:555-563.
[4] Hoffmann MH, et al. J Magn Reson Imaging. 2005;21(3):310-316.
[5] Wang Y, et al. Magn Reson Med. 2005;54:1123-1129.