Quantitative Assessment of the Myocardial Perfusion Reserve at 3.0T – Comparison of SR-TrueFISP and SR-TurboFLASH

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Introduction

Assessment of myocardial perfusion is a very promising concept for the noninvasive detection of coronary artery disease. Contrast-enhanced first-pass myocardial perfusion imaging using magnetic resonance imaging (MRI) has shown feasibility to provide insights into myocardial micro-circulation qualitatively [1], semiquantitatively [2,3], and quantitatively [4-8].

Typically, myocardial perfusion imaging is performed using saturation recovery (SR) prepared pulse sequences like spoiled gradient-echo pulse sequences (e.g. SR-TurboFLASH) [9] or balanced steady-state free precession pulse sequences (e.g. SR-TrueFISP) [10]. The imaging time of the pulse sequences can be reduced by using parallel acquisition techniques [11-13]. Recent work revealed an extended linear range between signal intensity and contrast media concentration in the blood by using parallel acquisition techniques in combination with different types of pulse sequences [14].

3.0T systems have become the standard for many applications in magnetic resonance imaging (MRI). The main advantage of the higher field strength is the higher bulk magnetization resulting in a theoretically increased signal-to-noise ratio (SNR), which is linearly related to field strength.

The aim of this study was to investigate and compare the two different pulse sequences SR-TurboFLASH and SR-TrueFISP at the magnetic field strength of 3.0T for quantitative myocardial stress and rest perfusion imaging. Comparisons were performed with regard to image quality and in particular with regard to semi- and quantitative analysis of the myocardial perfusion reserve (MPR). Therefore, both pulse sequences were tested for their intraobserver variability in the calculation of MPR.

Material and Methods

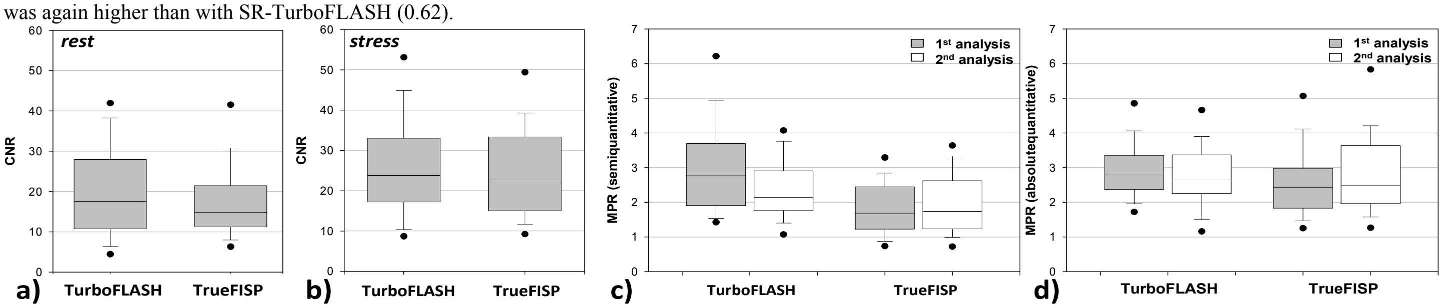
16 healthy volunteers were measured by first pass myocardial perfusion MRI at stress and rest. All measurements were performed on a 3.0T clinical MRI system (Magnetom Trio, Siemens Medical Solutions, Germany). For signal reception, a six-element phased-array cardiac coil was used in combination with six elements of the spine array. In all pulse sequences, the magnetization was prepared using a non-selective saturation pulse with a saturation time TI of 100ms. The repetition time (TR), echo time (TE), flip angle (α), and bandwidth were for SR-TurboFLASH 2.2ms/1.2ms/20°/890Hz/Px, and for SR-TrueFISP 2.2ms/1.0ms/~33.5°/1390Hz/Px. In the case of the SR-TrueFISP pulse sequence, the flip angle had to be adapted individually for every volunteer due to high energy deposition of this pulse sequence and the subsequent SAR (specific absorption rate) limitation. The raw data matrix size for all pulse sequences was 144x108 with a field of view (FOV) of 360x270 mm^2 resulting in a pixel size of 2.5 x 2.5 mm^2. The slice thickness was 8 mm. GRAPPA was used with an acceleration factor of 2 and 18 reference lines.

Each volunteer underwent a perfusion measurement at pharmacologic induced stress using adenosine with an injection rate of 140 µg/kg/min followed by a second perfusion measurement 30 minutes later at rest to calculate for the MPR. In 8 volunteers, the SR-TurboFLASH and in 8 volunteers the SR-TrueFISP pulse sequence was used. The time between the two subsequent perfusion measurements was at least 30 minutes to avoid errors due to remaining contrast agent in the body. In each perfusion series, 3 ml of Gd-DTPA (Magnevist, Schering, Germany) were injected with an injection rate of 5 ml/sec followed by a saline-flush of 40 ml.

Signal- and Contrast-to-Noise Ratio (SNR, CNR) were calculated from signal-time-curves (STC) in the myocardium. Semiquantitative calculation of the myocardial perfusion reserve (MPR) was performed by using a linear fitting method of the STCs at rest and stress und subsequent division of the stress upslope by the rest upslope. Absolutquantification of the myocardial blood flow (MBF) and MPR was performed by using the MMID4 model. Both, semiquantitative and absolutequantitative calculation of the MPR using either the SR-TurboFLASH or SR-TrueFISP pulse sequence was tested for their intraobservervariability. Therefore, all measurements were analyzed twice by one observer and the so called concordance correlation coefficient (CCC) was calculated for the results of the first and second analysis.

Results

Figure 1 shows results of the presented study. In a) and b), CNR is shown for both used pulse sequences, where in a) CNR at rest and in b) CNR at stress is shown. No differences were found for both pulse sequences neither at rest or stress. Figure 1 c) shows the MPR values resulting from the semiquantitative analyses. Significant differences ($P<0.01$) were found between both pulse sequences (median MPR with SR-TurboFLASH was 2.76 in the 1st 2.16 in the 2nd analysis, with SR-TrueFISP the median MPR was 1.68 and 1.74, respectively. The CCC value with SR-TrueFISP (0.84) was much better than with SR-TurboFLASH (0.36). Figure 1 d) shows the results from absolutequantification. Here, no differences in MBF values were found between both pulse sequences. However, the CCC value with SR-TrueFISP (0.94) was again higher than with SR-TurboFLASH (0.62).



Discussion

Results of this study show no differences in SNR or CNR in STCs using the both pulse sequences. This results from reduced flip angle using the SR-TrueFISP pulse sequence at 3.0T due to higher energy deposition and the SAR limitiation. However, SR-TrueFISP yielded more robust and reproducible perfusion analyses and, therefore, seems to be the best choice for quantitative myocardial perfusion imaging even at the field strength of 3.0T. Absolute quantification of the MBF to calculate for the myocardial perfusion reserve is superior in reproducibility to semiquantitative perfusion analysis.

References

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