

Quantitative Myocardial Perfusion Imaging Using Different TSENSE Accelerated Pulse Sequences

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Introduction

Reduced myocardial perfusion will be the first effect of stenotic coronary artery disease (CAD) [1]. Therefore, quantitative assessment of myocardial perfusion with first-pass magnetic resonance imaging is a very promising concept for non-invasive detection of CAD.

Most commonly used pulse sequences for myocardial MR perfusion imaging are spoiled gradient-echo pulse sequences like SR-TurboFLASH [2] or segmented echo-planar-imaging [3]. Recently, balanced steady-state free precession pulse sequences like TrueFISP with saturation recovery (SR) preparation have been introduced for myocardial perfusion imaging [4]. The scan time of the pulse sequences can be reduced by using parallel acquisition techniques like SMASH [5] or SENSE [6]. Techniques like TSENSE [7] were designed especially for dynamic imaging by combining the parallel imaging strategy with time-interleaved k-space acquisition as in UNFOLD [8]. A twofold acceleration is achieved by alternating between even and odd k-space lines from acquisition to acquisition. Therefore, coil sensitivity maps required for the SENSE-reconstruction can be derived from the data itself without needing a prescan or reference lines. Recent work revealed an extended linear range when using TSENSE in combination with different types of pulse sequences [9]. This should increase reliability of quantification of myocardial perfusion.

The purpose of this study was compare three TSENSE-accelerated pulse sequences for quantitative myocardial perfusion imaging (SR-TurboFLASH, SR-TrueFISP, SR-segEPI). Absolute myocardial blood flow (MBF) values were calculated using XSIM with the MMID4 model [10].

Material and Methods

All experiments were performed on a 1.5T clinical whole-body cardiovascular MRI system (Magnetom Sonata; Siemens Medical Solutions, Erlangen, Germany). For signal reception, a six-element phased-array cardiac coil was used in combination with two elements of the spine array. Six healthy volunteers were examined by first pass myocardial perfusion imaging at rest.

In all pulse sequences, the magnetization was prepared using a non-selective saturation pulse. The parameters TI/TR/TE/ α for SR-TurboFLASH were 125ms/2.4ms/1.2ms/18°, for SR-TrueFISP 125ms/2.2ms/1.1ms/50°, and for segmented EPI (echo train length of 4) 125ms/5.8ms/1.2ms/35°. The matrix size for all sequences was 128x96 with a field of view (FOV) of 380x285mm² resulting in a pixel size of 2.97x2.97mm². No additional temporal filtering for further suppression of aliasing artifacts has been applied with TSENSE.

In the volunteer study 40 measurements with 3 slices per heartbeat were acquired during a single breath hold. In all volunteers, 2ml of Gd-DTPA (Magnevist, Schering, Germany) were injected (-0.015mmol/kg of body weight) in an antecubital vein (injection rate = 8 ml/sec). For absolute quantification of MBF from baseline-corrected signal-time-curves, XSIM software (National Simulation Resource, Univ. of Washington, Seattle) was used with the MMID4 model as described in [11]. For all comparisons, a Wilcoxon signed rank test was used.

Results

Significant MBF differences were found between SR-TurboFLASH and SR-segEPI compared to SR-TrueFISP ($p < 0.005$ and $p < 0.001$, respectively) (c.f., figure 1). The differences between SR-TurboFLASH and SR-segEPI were not statistically significant ($p = 0.061$). The median MBF values for SR-TurboFLASH, SR-TrueFISP, and SR-segEPI were 0.766 (inter-quartile-range (IQR) 0.643 to 0.921), 0.905 (IQR 0.775 to 1.018), and 0.715 (IQR 0.593 to 0.865), respectively.

The fit quality was significantly lower with SR-TurboFLASH (median coefficient of determination (R^2) = 0.831, $p < 0.001$) and SR-segEPI (median R^2 = 0.861, $p < 0.001$) compared to SR-TrueFISP (median R^2 = 0.923). The differences in R^2 between SR-TurboFLASH and SR-segEPI were also statistically significant ($p = 0.01$) (see figure 2). Figure 3 shows signal-time-curves and their MMID4-fits to the corresponding median R^2 for each pulse sequence (note that the STCs and MMID4-fits in figure 3 are not in the same volunteer, they rather show the median fit quality for each pulse sequence).

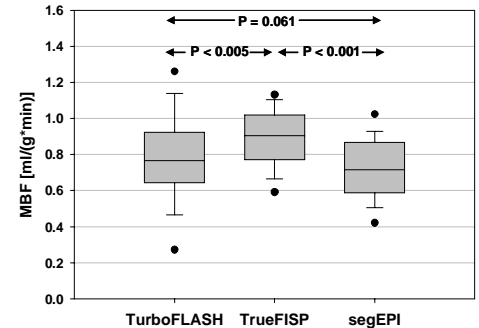


Figure 1: MBF values for SR-TurboFLASH, SR-TrueFISP and SR-segEPI.

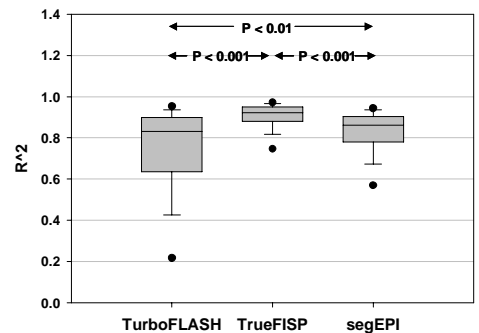


Figure 2: Median R^2 of the MMID4-fits for SR-TurboFLASH, SR-TrueFISP and SR-segEPI.

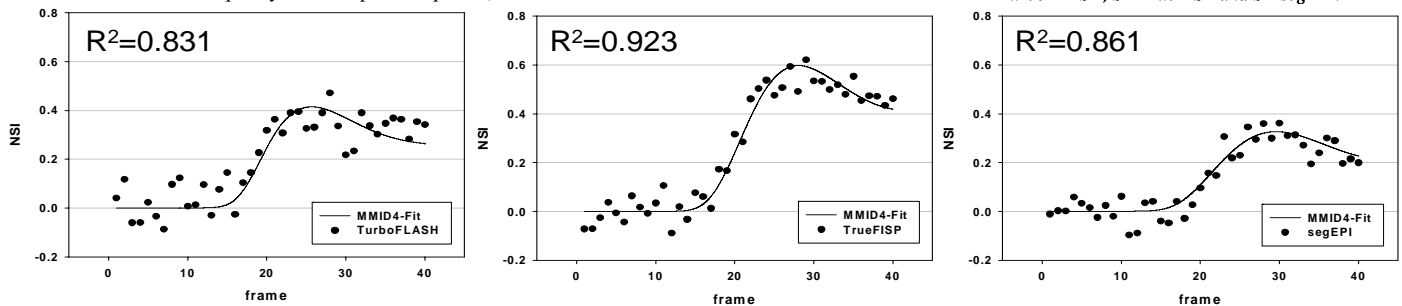


Figure 3: Signal-time-curves and appropriate MMID4-fits for each pulse sequence corresponding to the median R^2 value.

Discussion

SR-TrueFISP using TSENSE yields higher signal- (SNR) and contrast-to-noise-ratios (CNR) as well as better overall image quality than SR-TurboFLASH and SR-segEPI. This has been demonstrated recently [9]. This study shows that also fit quality in absolute quantification of MBF when using XSIM with MMID4 model is significantly enhanced if the SR-TrueFISP pulse sequence is used. The better fit quality should yield more reliable MBF values. The derived MBF values are in the range [12] expected for young healthy volunteers.

Acknowledgement

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References

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