Quantitative Myocardial Perfusion Imaging using Parallel Acquisition Techniques

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Introduction

Quantitative first-pass myocardial perfusion imaging needs a fast and robust pulse sequence to cover the whole heart within a single heartbeat. Rapid, multi-slice, T1-weighted imaging is often achieved using saturation recovery (SR) prepared pulse sequences with a short saturation time (TI) and an ultra-fast echo-readout like in spoiled gradient-echo pulse sequences (e.g. SR-TurboFLASH [1]). Recently, SR-prepared balanced steady-state free precession pulse sequences like SR-TrueFISP were proposed for myocardial perfusion imaging [2]. The imaging speed in MRI can be accelerated by using parallel acquisition techniques (PAT). Recent strategies for dynamic imaging like TSENSE [5] combine PAT with the UNFOLD [6] approach. The aim of this study was to compare the three auto-calibrated parallel imaging techniques GRAPPA [7], mSENSE [8], and TSENSE for quantitative myocardial perfusion imaging using a SR TrueFISP pulse sequence.

Material and Methods

Imaging was performed at 1.5T using a Siemens Sonata (Siemens Medical Solutions, Germany) whole-body MRI system. For signal reception a six-element phased-array cardiac coil in combination with two elements of the spine-array were used. Seven healthy volunteers were examined by first pass myocardial perfusion imaging at rest. In addition, the relation between signal intensity (SI) and contrast media (CM) concentration was determined for the SR-TrueFISP sequence with and without each PAT method using phantoms with blood- and myocardium equivalent relaxations times. This relation has to be linear in order to be suited for the quantitative analysis of myocardial blood flow (MBF). Recent work revealed an extended linear range when using TSENSE in combination with different types of pulse sequences [9].

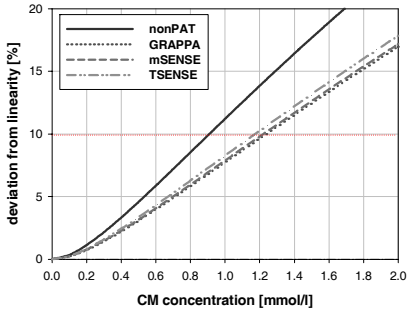

***Fig. 1**: Percentage deviation from a linear relation of SI and CM concentration for SR-TrueFISP without and with PAT.*

For SR-TrueFISP, the magnetization was prepared using a non-selective saturation scheme. With PAT the TI could be decreased from 125ms to 85ms. The parameters TR/TE/α were 2.2ms/1.1ms/50°, matrix 128x96, field of view (FOV) 380x285mm2, pixel size 2.97x2.97mm^2. No additional temporal filtering for further suppression of aliasing artifacts has been applied with TSENSE. In the volunteer study 40 measurements with 2 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).

Signal-to-noise ratios (SNR) in the myocardium were measured before CM administration (pre-SNR) and during maximum CM concentration (peak-SNR). Contrast-to-noise ratios (CNR) were calculated from pre- and post-SNR values. For absolute quantification of MBF from baseline-corrected signal-time-curves, XSIM software (National Simulation Resource, University of Washington, Seattle) was used with the MMID4 model [10]. In addition, all acquisitions were qualitatively evaluated by two experienced observers for image noise, PAT artifacts, and dark banding artifacts in the myocardium while CM flow through the ventricles (score from 1 to 4). The overall image quality was scored from 1 (very good) to 5 (non-diagnostic).

Results

The linear range of the relation of SI and CM concentration was extended to higher concentrations for the SR-TrueFISP with all three PAT methods due to the shortened TI and the fewer phase encoding steps. A deviation of 10% from the assumption of a linear relation occurred at about 40% higher CM concentrations compared to nonPAT. The differences between the three PAT methods were negligible (Fig. 1).

As expected, all three PAT methods introduced significant loss in SNR and CNR. GRAPPA yielded slightly higher values than both SENSE techniques. No significant differences were found between mSENSE and TSENSE (Fig. 2 and Fig. 3).

No differences were found in MBF between all three PAT methods and the conventional SR-TrueFISP acquisition. The median MBF values for nonPAT, GRAPPA, mSENSE, and TSENSE were 1.00±0.05, 1.08±0.05, 1.05±0.05 and 1.07±0.05, respectively. However, the variance of the measured MBF values was decreased when using PAT (Fig. 4).

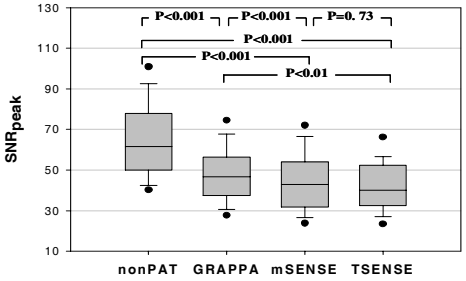

***Fig. 2**: Peak-SNR for SR-TrueFISP without and while using PAT (R=2).*

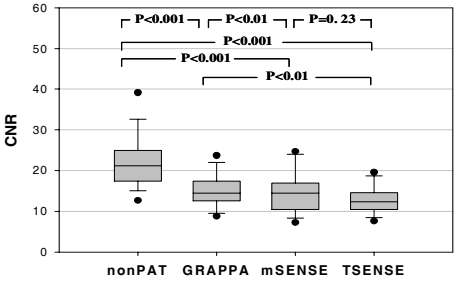

***Fig. 3**: CNR for SR-TrueFISP without and while using PAT (R=2).*

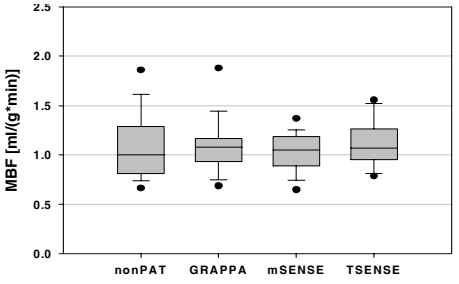

***Fig. 4**: MBF values for SR-TrueFISP without and while using PAT (R=2).*

With mSENSE and TSENSE significant residual PAT artifacts occurred. However, these artifacts were scored with mean score smaller than 2, i.e. not influencing the diagnostic quality. GRAPPA showed no residual PAT artifacts. With all techniques dark-banding artifacts occurred in the SR-TrueFISP images. However, no differences were found in terms of artefact occurrence between the acquisitions without PAT or with GRAPPA, mSENSE, and TSENSE. With all three PAT methods the image noise significantly increased when compared with nonPAT. The overall image quality was significantly reduced compared to nonPAT only with mSENSE. Furthermore, with mSENSE aliasing artifacts in full-FOV-images can lead to residual artifacts in the reconstructed images resulting in probably non-diagnostic images.

Discussion

Quantitative myocardial perfusion imaging can significantly benefit from PAT despite several drawbacks in SNR, CNR, and artifacts. The acquisition time per image can be decreased and thus, more slices can be acquired for better volume coverage of the heart. The increased linear range of the pulse sequence might be exploited for improved quantification of myocardial blood flow even with higher CM concentrations. Among the three auto-calibrated PAT methods GRAPPA yielded slightly better SNR and CNR values as well as better quality scores than both SENSE techniques. TSENSE yielded a higher acceleration because of his self-calibration nature without the need for reference lines as in GRAPPA and mSENSE. We suggest that GRAPPA and TSENSE are well suited for quantitative myocardial perfusion imaging.

Acknowledgement

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References

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