Comparison of three accelerated Pulse Sequences for Quantitative Myocardial Perfusion Imaging using TSENSE

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Introduction

Quantitative first-pass myocardial perfusion MR imaging requires a fast and robust pulse sequence to cover the whole human heart within a single heartbeat while simultaneous maintaining good image quality. Rapid, multi-slice, T1-weighted imaging is achieved by using a saturation recovery (SR) preparation pulse in combination with a short saturation time (TI) and an ultra fast gradient echo readout like spoiled FLASH, balanced steady-state free precession (bSSFP) or echo-train readout. Imaging speed can be accelerated by using parallel imaging techniques like SMASH [1] or SENSE [2]. Newer strategies for dynamic imaging combine the parallel imaging techniques with the UNFOLD [3] approach like TSENSE [4]. The aim of this study was to compare the established pulse sequences for myocardial perfusion imaging SR-TurboFLASH [4], SR-TrueFISP [5] and SR-Interleaved Gradient Echo-Planar Imaging (IGEPI) [6] while using the parallel imaging strategy TSENSE for faster image acquisitions. Measurements are performed at a low contrast agent dose regime for semiquantitative perfusion analysis.

Material and Methods

Imaging was performed on an 1.5T Siemens Sonata (Siemens Medical Solutions, Germany) using a six-element phased-array cardiac coil in combination with two elements of the spine array. A total of 24 healthy volunteers were examined by first pass myocardial perfusion imaging at rest. Thereby for each of the three pulse sequences 6 volunteers were examined with and without TSENSE (acceleration factor 2). Finally, 6 volunteers were examined with all three sequences using TSENSE only. Furthermore, the ratio between signal intensity (SI) and CA concentration was determined for each pulse sequence. This ratio has to be linear in order to be suited for (semi-) quantitative analysis of myocardial blood flow using phantoms with T1 and T2 relaxations times equivalent to those of myocardium.

In all pulse sequences, the magnetization was prepared using a nonselective saturation pulse. With TSENSE the TI could be decreased from 125ms to 85ms for all pulse sequences. The parameters TR/TE/α for TurboFLASH were 2.4ms/1.2ms/18°, for TrueFISP 2.2ms/1.1ms/50°, and for IGEPI (echo train length of 4) 5.8ms/1.2ms/ 35°. The matrix size for all sequences was 128x96 with a field of view (FOV) of 380x285mm^2 resulting in a pixel size of 2.97x2.97mm^2. No additional temporal filtering for further suppression of aliasing artifacts has been applied. For the volunteer study 40 measurements with 3 slices per heartbeat were acquired during a single breath hold. In all volunteers, 2ml of a Gd-based contrast agent (CA, Magnevist, Schering, Germany) were injected (~0.015mmol/kg BW) in an antecubital vein at an injection rate of 8 ml/sec.

Signal-to-noise ratios (SNR) in the myocardium were measured before CA administration (pre-SNR) and during maximum CA concentration (peak-SNR). Contrast-to-noise ratios (CNR) were calculated from pre- and post-SNR values. Furthermore, all acquisitions were qualitatively assessed by two experienced observers for TSENSE artifacts, dark banding artifacts in the myocardium while CA flow through the ventricles, sequence artifacts and image noise (score from 1 to 4). The overall image quality was scored from 1 (very good) to 5 (non-diagnostic).

Results

Because of the shortened TI and the fewer phase encoding steps, the linear range of the CA concentration-to- signal intensity relation was extended to higher concentrations for all three pulse sequences when using TSENSE (Fig. 1). On the basis of these results the CA dosage can be increased.

TSENSE introduced a median loss of SNR of 43%, 39% and 23% for TurboFLASH, TrueFISP and Interleaved Gradient EPI, respectively. For the peak-SNR the loss was 44%, 35% and 31% and for the CNR the loss was 45%, 40% and 16%, respectively. Using TSENSE the TrueFISP sequence yielded significantly higher SNR- and CNR-values than both of the other sequences, as well as the Interleaved Gradient EPI sequence yielded significantly higher values than TurboFLASH (Fig. 2 and Fig. 3). In the TrueFISP images significantly more dark banding artifacts appeared in the myocardium than in the other two sequences. No differences were found between the conventional and the TSENSE acquisitions. With TurboFLASH and Interleaved Gradient EPI the images showed significantly more image noise than with TrueFISP. TrueFISP yielded the best overall image quality while Interleaved Gradient EPI sequence yielded better results than TurboFLASH (Fig. 4).

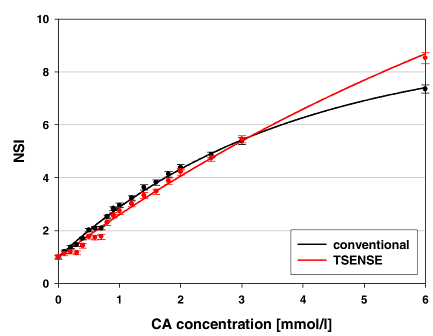

Fig. 1: The relationship between (normalized) signal intensity and CA concentration shows an increased linearity of the pulse sequence when using TSENSE. (Example for the Turbo-FLASH sequence)

Discussion

With TSENSE the acquisition time per image can be decreased. Therefore, the number of acquired slices can be increased for all sequences for better volume coverage of the heart. The increased linearity of the CA-concentration to signal-intensity relation may provide a more reliable quantification of myocardial perfusion. With TSENSE the TrueFISP sequence provides the highest SNR and CNR values as well as the best overall image quality. It is therefore suited best for (semi-) quantitative analyses of myocardial perfusion. The Interleaved Gradient EPI sequence may advance future clinical perfusion imaging because of shorter acquisition times, a greater linearity range, fewer dark banding artifacts in the myocardium and smaller SNR and CNR reduction with TSENSE.

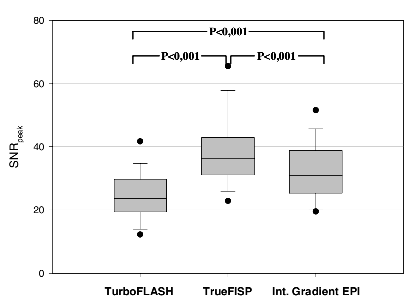

Fig. 2: Peak-SNR for TurboFLASH, True-FISP and IGEPI using TSENSE.

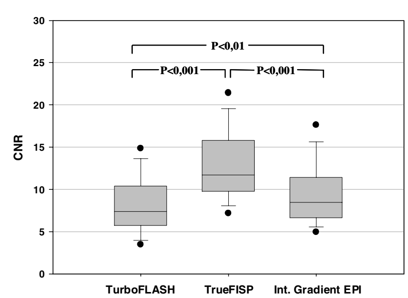

Fig. 3: CNR for TurboFLASH, TrueFISP and IGEPI using TSENSE.

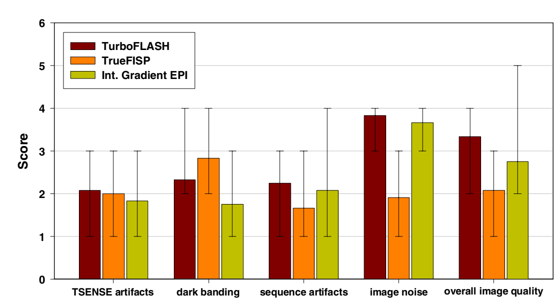

Fig. 4: Quality assessment for the three pulse sequences using TSENSE. (Mean values, minima and maxima)

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