Accelerating cardiac perfusion imaging – signal-to-noise considerations

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Introduction

The requirements of contrast-enhanced myocardial perfusion MR imaging for high spatial resolution and full cardiac coverage while keeping a sufficiently short acquisition window have led to extensive research into combining conventional acquisition schemes with speed-up techniques (1,2). Inherently, any gain in speed is associated with a loss in signal-to-noise ratio. In parallel imaging, nonorthogonality of coil encoding leads to a further penalty resulting in spatially varying noise amplification (3). This penalty becomes significant when approaching and exceeding the critical reduction factor beyond which noise amplification grows exponentially (4). Methods that jointly exploit coil encoding and spatiotemporal correlations have been proposed, which allow for speed-up factors beyond the critical reduction factor seen with parallel imaging. Among other methods, *k-t* SENSE (5) has shown its potential for accelerating cardiac perfusion imaging (6). The *k-t* SENSE method relies on adaptive filtering in the spatio-temporal frequency or x-f domain which is very sparse in dynamic perfusion data. Accordingly, a large number of data points in the x-f domain can be assigned background points thereby reducing the number of unknowns in the reconstruction problem efficiently. This results in improved signal-to-noise ratios for image pixels requiring less than the available temporal bandwidth relative to methods reconstructing frame-by-frame. The assessment of signal-to-noise performance of parallel and transform coding imaging in a practical setting is complicated by the spatially varying noise amplification. Noise amplification depends on coil nonorthogonality in general and temporal characteristics in the object in *k-t* SENSE in particular. In this work, contrast bolus perfusion images were acquired in volunteers with 2x SENSE and 5x *k-t* SENSE at both 1.5T and 3.0T to assess relative signal enhancement and relative signal-to-noise ratios.

Methods

A volunteer study (N=8) was carried out on 1.5T and 3.0T Philips MR systems (Philips Medical Systems, Best, The Netherlands) using a 5-element and 6-element cardiac phased-array coil on 1.5T and 3.0T, respectively. Saturation recovery segmented gradient echo sequences (TR: 2.7-3.1 ms, TE: 0.9-1.1 ms, flip angle: 15 deg, saturation prepulse delay: 150 ms, 62.5% partial Fourier) were employed following intravenous administration of 0.1 mmol/kg Gd-DTPA. The receiver bandwidths on 1.5T and 3.0T were kept identical.

In each volunteer, 2x SENSE and 5x *k-t* SENSE imaging were performed. Taking into account 11 training profiles acquired interleaved with the actual undersampled data the net acceleration in *k-t* SENSE was 3.8. Spatial resolution was 1.1x1.1-1.5x1.5x10 mm^3, training data plug-in was used and the acquisition window was 120ms. In order to maintain identical acquisition window durations, spatial resolution in 2x SENSE imaging was lowered relative to the 5x *k-t* SENSE protocol. In one volunteer, fully sampled perfusion data were acquired additionally to enable simulation work based on decimated data with reference to ground truth (acquisition window: 240 ms, spatial resolution 2.7x2.8x10mm^3).In computer simulations the fully sampled data were decimated to simulate 5x *k-t* SENSE data acquisition. Signal intensity curves from reconstructed data were compared relative to curves obtained from fully sampled data. Peak relative signal enhancement was calculated between baseline images and the image at peak myocardial contrast uptake. Signal-to-noise ratios were calculated and normalized to unit voxel size to account for differences in spatial resolution between *k-t* SENSE and SENSE. Signal intensity curves were extracted in the myocardium using standard post-processing software. Signal-to-noise ratios (SNRs) were calculated for the myocardial wall upon contour segmentation. SNR values were derived from the mean and the difference of adjacent time-frames according to the method proposed previously (7).

Results

Signal intensity curves from 5x *k-t* SENSE simulations relative to the values from fully sampled data are shown in Figure 1. It is seen that the temporal characteristic of the perfusion signal is well preserved with only little deviations from the reference. Figure 2 shows a comparison of relative signal-to-noise ratios over time between 5x *k-t* SENSE and 2x SENSE at 1.5T. The ratio of SNR in 5x *k-t* SENSE to 2x SENSE was found to be 1.8±0.3 on average over all volunteers. Peak relative signal enhancement between 5x *k-t* SENSE and 2x SENSE at 1.5T showed no significant differences (151.0% vs 149.7%). Comparing the ratios of SNR between 3.0T and 1.5T for 5x *k-t* SENSE a factor of 2.2±0.4 was calculated which, when corrected for the difference in number of coil elements, yielded a factor of 2.06 on average (Figure 3).

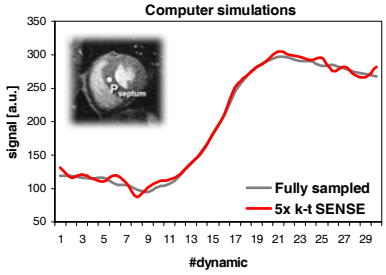

***Figure 1**. Computer simulations. 5x k-t SENSE was simulated based on fully sampled in-vivo data and signal intensity curves for a 3x3 region (P_{septum}) was assessed relative to the reference.*

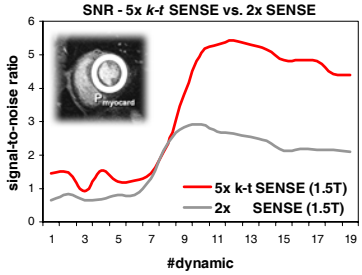

***Figure 2**. Comparison of normalized SNR averaged over the myocardial area ($P_{myocard}$) with 5x k-t SENSE relative to 2x SENSE acquired in the same volunteer.*

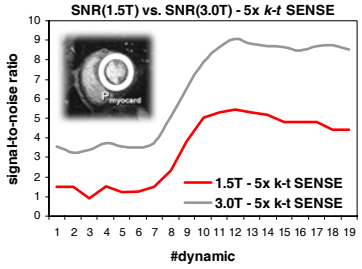

***Figure 3**. Comparison of normalized SNR across the myocardium $P_{myocard}$ of 5x k-t SENSE between 1.5T and 3.0T imaging with otherwise identical parameter settings.*

Discussion

The sparseness of dynamic perfusion data allows for efficient speed-up while preserving relatively high SNR. The SNR benefit with *k-t* SENSE can be related to the smaller bandwidth required to describe temporal contrast update in the myocardium relative to the available temporal bandwidth of the scan. In this volunteer study 5x *k-t* SENSE was found to be robust with regard to temporal fidelity in the data. The achievable signal enhancement was similar between the two methods studied at around 150% enhancement at rest which appears sufficient for clinical application. It is concluded that 5x *k-t* SENSE presents a valuable method to image perfusion in the heart. Further work is necessary to study the effects of gross cardiac bulk motion due to sudden respiratory jerks which were excluded in this study.

References

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