Compressed Sensing Cardiac Perfusion Imaging

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Introduction

In myocardial perfusion, several requirements must be met in order to acquire diagnostically meaningful data sets. The most important among them are: a) high spatial resolution, b) high temporal resolution and c) adequate coverage [1]. However, as it is generally the case in dynamic MRI, there is a trade-off between the achievable temporal and spatial resolutions. In order to relax this trade-off and accelerate perfusion imaging, techniques which exploit either spatial [2] or spatiotemporal correlations [3, 4] have been proposed. Excellent resolution in space and time has been achieved using *k-t* SENSE [3], which performs reconstruction by exploiting spatiotemporal *redundancy* present in perfusion images.

In this work, we investigate the potential of Compressed Sensing (CS) [5] as a method to accelerate perfusion imaging. Compressed Sensing has been proposed to efficiently accelerate dynamic MRI (cine, angiography) [6] by exploiting the implicit *sparsity* of dynamic images or suitable transformations thereof. The objective of the present work was to demonstrate the feasibility and limitations of CS perfusion in comparison to *k-t* SENSE based on computer simulations and actual *in vivo* examinations.

Methods

A fully sampled non-accelerated perfusion scan was acquired on a 3T Philips Achieva system (Philips Medical Systems, Best, NL) using a saturation recovery turbo field echo (TFE) sequence and a six channel cardiac coil array. The reconstruction matrix was 256x192 with 40 dynamics. To allow for quantitative assessment of the reconstruction result, the data set was decimated to simulate nominal acceleration factors ranging from 2x up to 8x. For CS, the data were undersampled randomly in the *k-t* space; for *k-t* SENSE undersampling was according to a sheared grid pattern [7], with training data consisting of 11 profiles acquired at two-fold reduced FOV and reconstructed using SENSE [8]. The reconstruction of the randomly undersampled data was performed in the spatiotemporal frequency domain (*x-f* space) using a steepest descent algorithm along the energy difference between the reconstructed and the measured *x-f* space [9,10]. In a subsequent step, 5x accelerated perfusion scans (net acceleration 4.1x) were performed *in vivo* using the following parameters: spatial resolution: 1.3x1.3x10mm^3, FOV: 380x300mm^2, saturation recovery TFE, saturation delay:125ms, acquisition window: 90ms, flip angle: 20^o, T_R/T_E: 2.6/0.92mm, 30 dynamics. The interval between the *k-t* SENSE and CS scans was 20 minutes to allow for sufficient wash-out of the contrast agent.

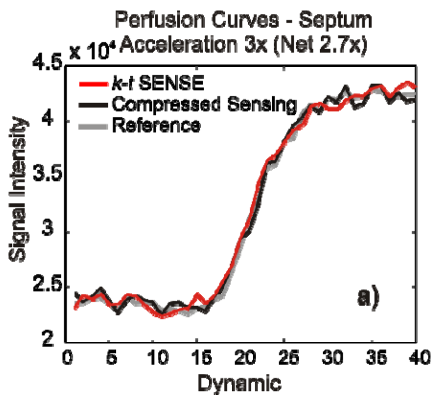

***Figure 1**. Comparison of perfusion curves from 3x Compressed Sensing and 3x k-t SENSE reconstructions for a region-of-interest on the septal wall (a). Another comparison for the same region, this time with 5x acceleration (b).*

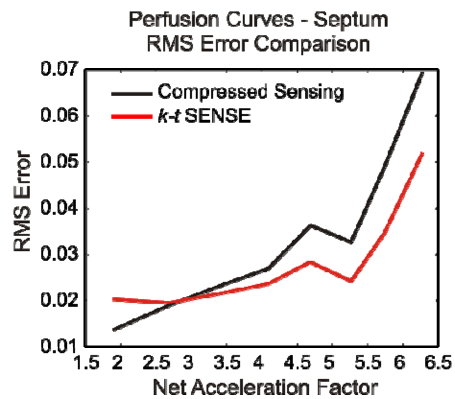

***Figure 2**. Root-mean-square (RMS) errors of perfusion curves from Compressed Sensing and k-t SENSE as a function of net acceleration.*

Results

Figure 1a and 1b compare the perfusion curves acquired for a region-of-interest on the septum for acceleration factors of 3x and 5x, respectively. It is seen that both methods result in perfusion curves that agree well with the curves extracted from the fully sampled reference data set. As Figure 2 demonstrates, CS outperforms *k-t* SENSE for low acceleration factors. Beyond a reduction factor of 3, *k-t* SENSE yields lower RMS errors. However, the trait of the artifacts seen for the two methods at similar RMS error levels differs, particularly for higher acceleration factors. CS features incoherent, noise-like artifacts which might be less disturbing to the eye of the observer, whereas *k-t* SENSE results in residual ghosting and some slight temporal filtering. *In-vivo*, both CS and *k-t* SENSE were found to provide similar image quality, however with increased noise in the signal-intensity curves from CS data (Figure 3).

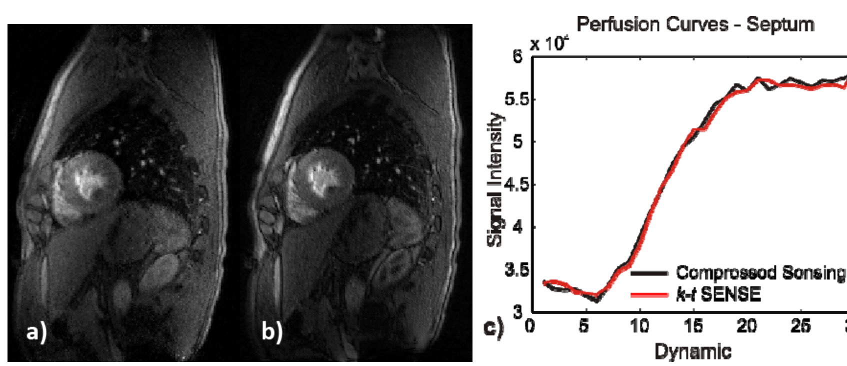

***Figure 3**. 5x Compressed Sensing (a) and k-t SENSE (b) reconstructed perfusion scans (dynamic 22 of 30) and comparison of the corresponding perfusion curves (c).*

Discussion

In conclusion, Compressed Sensing features interesting properties for accelerating perfusion imaging. Up to an acceleration factor of approximately 3 (depending on the sparsity of the data and implicitly on the signal-to-noise ratio), this reconstruction yields lower RMS errors when compared to *k-t* SENSE. To achieve sufficient image quality for accelerations beyond a factor 5, incorporation of coil encoding as a joint encoding mechanism seems necessary [11].

References

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