

Accelerating Arterial Spin Labeled Perfusion Imaging Using Compressed Sensing

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INTRODUCTION:

First-pass perfusion MRI after the bolus injection of gadolinium-based contrast agent is often applied to assess end organ perfusion in the heart [1] and muscle [2]. However, patients with renal insufficiency are at risk of nephrogenic systemic fibrosis [3] with a gadolinium based MRI contrast agent. An alternative method to assess end organ perfusion is to use arterial spin labeled (ASL) MRI method, without administration of any contrast agent. Many applications of this method were reported in heart, muscle, etc. [4,5]. However, this method is sensitive to motion artifacts, due to prolonged data acquisition time for each T1 weighted image. The motion artifacts will greatly degrade the image quality and reduce the accuracy of perfusion measurements. Reduction of data acquisition time is preferred to minimize motion artifacts. In this study, the feasibility of accelerating ASL acquisition using compressed sensing is investigated.

METHODS:

Imaging techniques: ASL sequence was used assessing perfusion in skeletal muscle of calf and myocardium in normal volunteers. This is FAIR type of ASL [6] with acquisitions of myocardial T₁s using slice-selective and non-selective 180° pulses. Single-shot gradient-echo acquisition was performed to obtain each T1-weighted signal. In the muscle data, TR/TE= 2.8/1.2ms, flip angle = 5°, FOV = 160 x 112 mm², matrix = 128 x 90, average = 3, total acquisition = 50 sec. For myocardial ASL sequence, TR/TE= 2.5/1.1ms, flip angle = 5°, FOV = 320 x 200 mm², matrix = 160 x 90, average = 1, total acquisition = 18 sec. To obtain the reduced acquisition retrospectively, the k-space data is randomly undersampled along the phase encoding direction at each time frame. Different sampling patterns are used at different time t. The central lines of the k-space are fully sampled for all times.

Reconstruction methods: Compressed Sensing has been shown to accelerate the acquisition speed in dynamic imaging applications [7-9]. It exploits the spatial and/or temporal correlation in the dynamic image sequence to sparsify these images in a transform domain. Then image sequence is obtained from the reduced undersampled data in (k,t)-space by: $\min_{\rho} \|F_y \rho - d\|_2 + \lambda_1 \|P\rho\|_1 + \lambda_2 \|\rho\|_{2,TV}$ where **d** is the undersampled (k,t)-space data, **ρ** the image sequence to be reconstructed, P the sparsifying transform, $\|\rho\|_{2,TV}$ denotes the L₂ (along time) of the total variation of each frame, and λ₁ and λ₂ are the regularization parameters. Nonlinear conjugate gradient method is used to solve this problem. The reconstruction quality highly relies on the choice of the sparsify

transform. Because ASL images are non-periodic and have strong correlation in the temporal dimension, we use the principle component analysis (PCA) to obtain the data-dependent sparsifying transform. Specifically, the low-resolution images from all time frames were used as the training data to perform PCA and obtain the sparsifying transform P.

RESULTS:

The results from both full and accelerated acquisition were compared visually and quantitatively. The acceleration factor of 2 was used in both experiments. Figures 1 and 2 show the results for the muscle data, and Figures 3-5 for the cardiac data. Figures 1 and 4 demonstrate the image quality of accelerated scan is comparable to that of the full scan. The intensity curves for the ROI in Figures 2 and 5 indicate the quantitative results of accelerated scan are also close to that of the full scan. The perfusion maps of myocardium are shown in Figure 3. In myocardium, the averaged global perfusion was 1.2 ± 0.9 ml/g/min using origin data set and 1.3 ± 0.7 ml/g/min using CS processed data set.

CONCLUSION:

In this study, we have used *in vivo* muscle and cardiac experiments to demonstrate the feasibility of accelerating ASL acquisition using compressed sensing. The reconstructed ASL image sequence, ROI intensity curves, and perfusion measurements obtained from undersampled data in (k,t)-space closely match the results from the full acquisition.

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