

Accelerated true-FISP Multi-slice First Pass Perfusion Imaging using TSENSE

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Synopsis

Parallel imaging is applied to first pass contrasted enhanced cardiac MR to yield greater spatial coverage for a fixed temporal resolution. The method combines true-FISP imaging with rate R=2 acceleration using TSENSE. Single heart beat temporal resolution was accomplished with spatial coverage of 6 slices at heart rates up to 80 bpm and 4 slices up to 120 bpm. Increased spatial coverage is demonstrated with consistently good contrast and overall image quality.

Introduction

Coverage of the entire heart during a first pass contrast enhanced MRI with single heartbeat temporal resolution is desirable for quantifying perfusion abnormalities. Current imaging protocols limit the ability to image the entire heart with single heartbeat temporal resolution, particularly at high heart rates. Multi-slice coverage may be achieved using saturation recovery with a relatively short preparation time (TI) and FGRE with echo-train readout [1]. Imaging quality may be improved at the expense of coverage [2] by increasing TI and readout flip angle. Alternatively, true-FISP imaging may be used with saturation recovery to produce high quality images without resorting to echo-train readout. The proposed method uses saturation recovery with a true-FISP readout, and uses accelerated imaging for greater spatial coverage.

Methods

Imaging time may be reduced by under-sampled acquisition with full-FOV reconstruction using either UNFOLD [3] or parallel imaging methods such as SENSE [4]. The TSENSE [5] method was used to adaptively estimate B₁-maps using an interleaved phase encode acquisition order with odd and even lines of k-space acquired on alternate heartbeats. No additional temporal filtering for further alias artifact suppression was applied to the TSENSE images. Off-line reconstruction was performed in software using MATLAB (The Mathworks, Natick, MA.).

Imaging was performed on a 1.5T Siemens Sonata using a true-FISP sequence with the following typical parameters: TR=2.2ms (echo spacing), 55° readout flip angle, 1200 Hz/pixel BW, 8mm slice thickness. Images were acquired from animal studies with infarct, as well as normal volunteer studies. For the results shown, images were acquired using an 8-coil array (Siemens) for the dog study and 8-coil array (Nova Medical, Wakefield, MA) for the human subject. For the dog study the acquisition matrix was 128x64 with FOV= 320x160 mm² corresponding to an in-plane resolution of 2.5x2.5 mm². For the volunteer study the acquisition matrix was 128x80 with FOV=350x240 mm² corresponding to an in-plane resolution of 2.7x3 mm². The TI was approximately 64ms, where TI is defined at the center of k-space acquisition rather than to the 1st readout as in [1,2]. The imaging time per slice (including all overhead) was 100.5 and 114.8 ms for the dog and normal volunteer studies, respectively. The number of slices acquired per heartbeat was 4 for the dog study at a heart rate of 117 bpm, and 6 slices per heartbeat for the volunteer study with heart rate of approx. 60bpm.

SNR measurements were made in the septal and inferolateral myocardial regions using noise measured during prescan. Contrast-to-noise ratios (CNR) and contrast enhancement ratios (CER) were calculated from pre- and post-contrast SNR values. The SENSE g-factor was estimated from the pre-scan noise and estimated B₁-maps.

Results

Fig.1 shows example images of a single SAX slice (of 4 acquired) during first pass perfusion for dog with occlusion in circumflex artery at following times: (a) pre-contrast, (b) RV enhanced, (c) LV enhanced, and (d) myocardium enhanced. The perfusion deficit in the region of occluded artery is clearly evident. The CNR between pre- and post-contrast for myocardium in the septal region was approximately 15 with a CER of approx. 3, and the post contrast CNR between normal and occluded region was measured to be approx. 13. Fig.2 shows example images of a single SAX slice (of 6 acquired) during first pass perfusion for a normal volunteer at following times: (a) pre-contrast, (b) RV enhanced, (c) LV enhanced, and (d) myocardium enhanced. In the septal region the SNR ≈ 10 pre-contrast and SNR ≈ 48 post-contrast (CNR ≈ 38, CER ≈ 4.8). In the inferolateral region the SNR ≈ 7 pre-contrast and SNR ≈ 35 post-contrast (CNR ≈ 28, CER ≈ 5). All images for each figure were window-leveled the same. The R=2 SENSE g-factor estimated for the normal volunteer study using the 8-coil linear array was less than 1.1 in region of interest.

Discussion

Multi-slice first pass perfusion true-FISP imaging with R=2 TSENSE acceleration has been demonstrated to achieve 2x spatial coverage with high quality image reconstruction. Reconstructions were performed using TSENSE without additional temporal filtering. Adaptive B₁-map estimates were artifact free and SENSE alias artifacts were suppressed to the noise level or below. Higher accelerations factors may be possible for either increased coverage, higher spatial resolution, or operation at higher heart rates, although SNR will be reduced due to reduced acquisition time as well as an increased loss due to the SENSE g-factor. Further quantitative performance characterization is ongoing.

References

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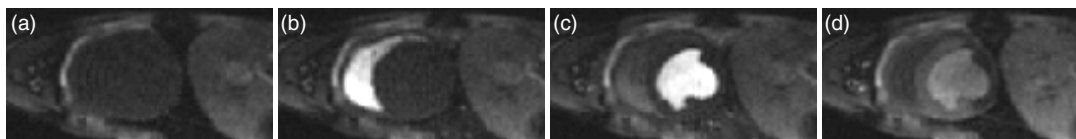


Figure 1. Example images of single SAX slice (4 slices per heartbeat acquired at 117 bpm) during first pass perfusion for dog with occlusion in CX artery: (a) pre-contrast, (b) enhanced RV, (c) LV enhanced, and (d) myocardium enhanced.

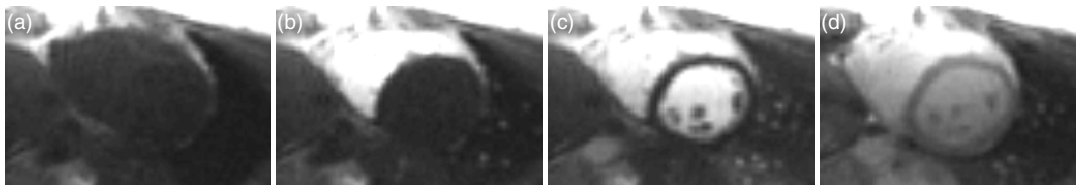


Figure 2. Example images of single SAX slice (6 slices per heartbeat acquired at 60 bpm) during first pass perfusion for normal volunteer: (a) pre-contrast, (b) enhanced RV, (c) LV enhanced, and (d) myocardium enhanced.