Cardiac First-pass Perfusion MRI using 3d trueFISP Parallel Imaging using TSENSE

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Introduction

Coverage of the entire heart during 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. Parallel imaging is applied to first-pass contrast enhanced cardiac MR to provide 3d coverage of the heart with single heartbeat temporal resolution. The method combines saturation recovery true-FISP imaging with rate R=6 acceleration using 2d TSENSE. Unlike multi-slice 2d perfusion imaging, 3d imaging is performed in end-diastole with all slices at the same cardiac phase, thereby enabling a longer saturation preparation time (TI) for improved contrast-to-noise ratio (CNR) and flatter response.

Methods

Cardiac perfusion 3d imaging was implemented on a Siemens Sonata 1.5T scanner using an ECG triggered trueFISP sequence. Parallel imaging using 2d SENSE [1] was used to reduce the number of lines aquired. Doubly oblique imaging was used with the partition encode along the long axis of the heart. The phase encode and frequency readout directions were in the short axis plane with the frequency readout along the longer dimension of the body after in-plane rotation was applied. The acquisition used rate R=3x2=6 undersampling, with rate 3 undersampling in the phase encode dimension and rate 2 undersampling in the partition encode direction. The B_1-maps were estimated using the auto-calibrating TSENSE method [2]. The *k*-space undersampling varied cyclically with complete *k*-space acquired in 6 phases. The complete dataset was integrated to reconstruct B_1-maps for calculating SENSE unmixing coefficients. Temporal filtering was not applied to the TSENSE reconstructed images. Since it is important to have artifact free in vivo reference images for B_1-map estimates 25% slice oversampling was used in the partition encode dimension to reduce wrap. The acquisition matrix was 128x78x10 with 2 slices discarded after reconstruction. The example shown used a FOV of 300x281x80 mm^3 providing a spatial resolution of 2.3x3.6x10 mm^3. The actual number of lines acquired were 78/3=26 phase encodes x 10/2=5 partition encodes. The sequence parameters were: bandwidth = 1400 Hz/pixel, TR=2.4 ms, 33° readout flip angle. The imaging duration was (78/3)x(10/2)x2.4 = 312 ms in end-disatole. A 90° saturation preparation was used with a TI=300 ms prep time measured to center of *k*-space.

A custom 8-element cardiac phased array (Nova Medical, Inc, Wakefield, MA) was used, consisting of two 4-element gapped linear arrays (22 cm x 5.25 cm element size with long dimension oriented along the S/I direction and approximately 1.25 cm gap in the L/R direction), with 1 array positioned on the chest, and the second array positioned on the back of the patient. SENSE g-factors [3] were estimated from the B_1-maps.

Images were acquired for 40 heartbeats beginning approximately 5 seconds prior to administering a single dose bolus (0.1 mmol/kg) of contrast agent (Gadopentetate Dimeglumine, Berlex Magnevist) at 5 ml/s followed by a saline flush (20 ml at 5 ml/s); contrast agent was administered intravenously in the left antecubital vein.

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 B_1-maps.

Results

Fig.1 shows example images for all 8 slices acquired during first pass perfusion for a normal healthy volunteer: (a) pre-contrast, (b) RV enhanced, (c) LV enhanced, and (d) myocardium enhanced. For a mid-basal slice, in the septal region the SNR ≈ 15 pre-contrast and SNR ≈ 39 post-contrast (CNR ≈ 24, CER ≈ 2.6). In the inferolateral region the SNR ≈ 4 pre-contrast and SNR ≈ 10 post-contrast (CNR ≈ 6, CER ≈ 2.5). All images for each figure were window-leveled the same. The R=6 SENSE g-factor estimated for the normal volunteer study using the 8-coil linear array had a mean value of 4.5 in the heart region.

Discussion

First-pass perfusion using true-FISP imaging with R=6 TSENSE acceleration has been demonstrated to achieve full heart coverage with high quality image reconstruction. Despite the relatively high g-factor for R=6 acceleration with only 8-coils, the SNR was quite good and SENSE alias artifacts were well suppressed. Improved performance is expected using a larger number of array elements and 2d array designs [4]. A larger flip angle may also be used. Higher accelerations factors may be possible for higher spatial resolution with a larger number of receiver channels.

References

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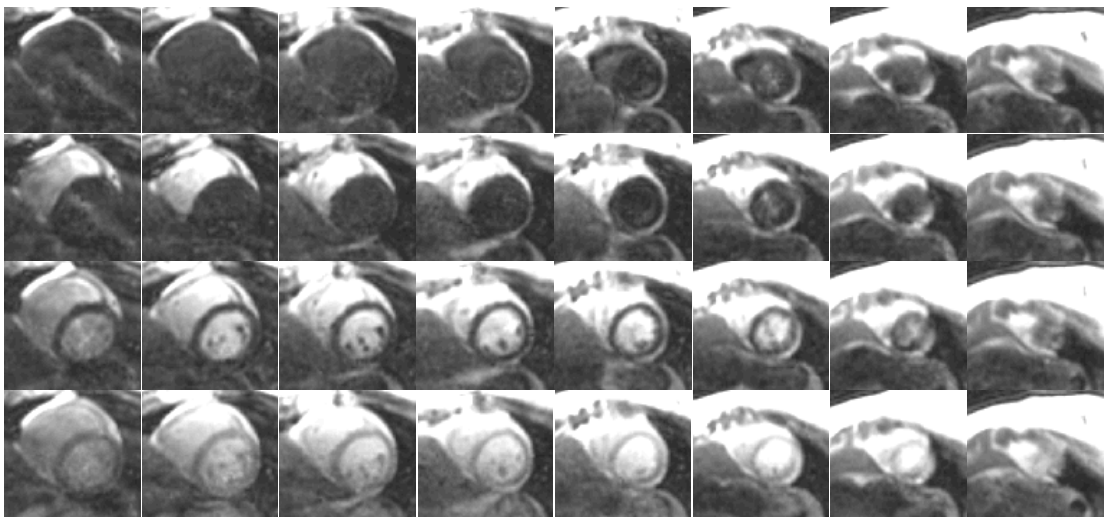

Figure 1. Example 1st pass 3d perfusion images using Rate=6 2d TSENSE showing pre-contrast, RV enhanced, LV enhanced, and myocardium enhanced for 8 slices.