Cardiac Cine 3d trueFISP Parallel Imaging using Auto-calibrating 2d-TSENSE

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Introduction

Cardiac cine 3d imaging offers the potential for full heart coverage in a single, segmented breath-held acquisition. A single acquisition eliminates breath-hold registration errors between slices in conventional 2d multi-slice imaging requiring multiple breath-holds. A trueFISP sequence combined with parallel imaging is used to achieve spatial resolution of 2.3 x 2.4 x 6 mm^3 and approximately 50 ms temporal resolution within a single 20 heartbeat breath-hold. Parallel imaging uses 2d-TSENSE at acceleration rate 6 with a custom 8-element surface coil array.

Methods

Cardiac cine 3d imaging was implemented on a Siemens Sonata 1.5T scanner using an ECG triggered trueFISP sequence with segmented *k*-space acquisition. Parallel imaging using 2d SENSE [1] was used to reduce the breath-hold duration. 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 128x108x20 with 4 slices discarded after reconstruction. The example shown used a FOV of 300x281x96 mm^3 providing a spatial resolution of 2.3x2.6x6 mm^3. The actual number of lines acquired were 108/3=36 phase encodes x 20/2=10 partition encodes. The sequence parameters were: bandwidth = 1400 Hz/pixel, TR=2.84 ms, 50° readout flip angle. There were 18 views per segment providing 18x2.84 ms=51 ms temporal resolution. The total beath-hold duration was (108/3)x(20/2)/18 = 20 heart beats.

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 prescan noise and the B_1-maps.

Results

Example images for systolic and diastolic cardiac phases are shown in Figure 1 for a normal volunteer. The mean g-factor is estimated to be approximately 4 in the heart region.

Discussion

Cardiac 3d cine MRI using 2d parallel imaging was demonstrated for single breath-hold acquisition. Scan time may be further reduced by using elliptical scanning and using a faster RF pulse for reduced TR. Despite relatively high g-factors for rate 6 using 8 coils, the SNR and artifact suppression were quite good. Although it was possible to use a linear array for 2d SENSE due to the oblique slice orientation [4], parallel imaging performance is expected to improve with larger arrays and using 2d geometries. At higher accelerations, it may be possible to approach isotropic resolution and thereby display both short and long axis views from a single acquisition.

References

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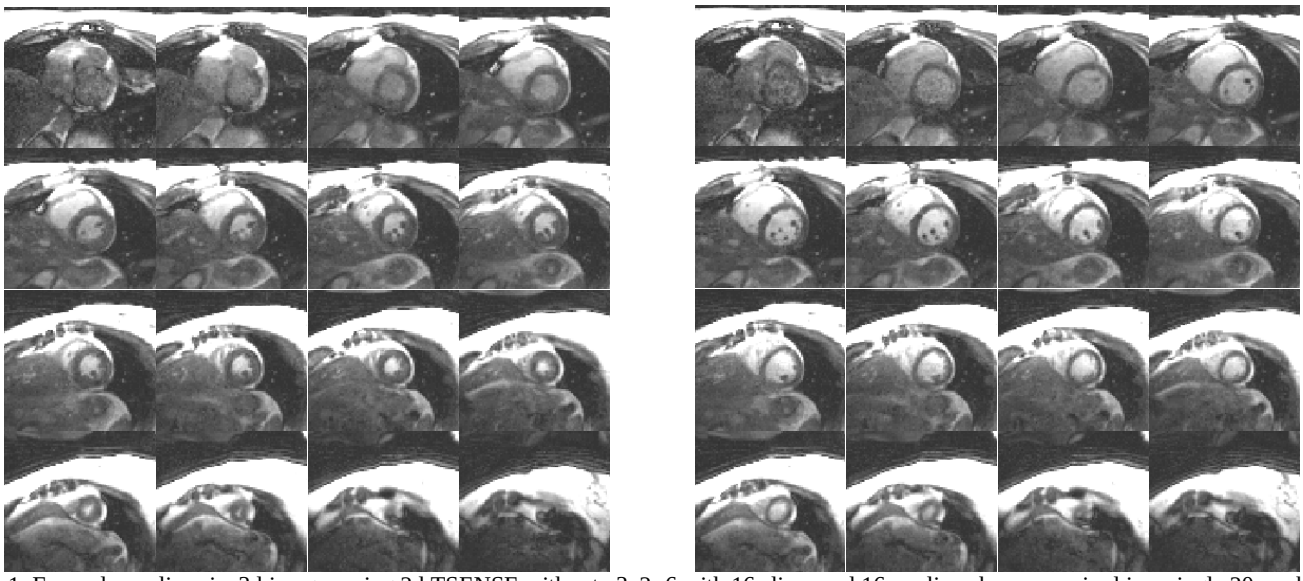

Figure 1. Example cardiac cine3d images using 2d TSENSE with rate 3x2=6 with 16 slices and 16 cardiac phases acquired in a single 20 sec breath-hold. Images shown at (a) systolic and (b) diastolic phases.