SENSE Accelerated 3D Imaging of Myocardial Infarction using Phase Sensitive Inversion Recovery

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Synopsis

Following administration of gadolinium, infarcted myocardium exhibits delayed hyperenhancement and can be imaged using a true-FISP (SSFP) sequence. We present experimental results that demonstrate 3-d imaging with phase sensitive inversion recovery (PSIR) acquired in a single breath-hold using parallel MR based on the SENSE method [1]. PSIR has a number of benefits [2] including consistent contrast and appearance over a relatively wide range of inversion recovery times (TI), improved contrast-to-noise ratio, and consistent size of hyperenhanced region.

Methods

The parallel MR SENSE method is applied to 3d imaging in the phase encode dimension to reduce the number of phase encodes by a factor R=2. In this manner it is possible to acquire the entire 3d volume in a single breath-hold acquisition. Using a true-FISP imaging sequence with rate R=2 SENSE, the complete set of phase encodes (k_y) for each partition encode (k_z) is acquired in a single heartbeat. Using Gd-DTPA with an inversion recovery acquisition sequence it is desirable to use 2 heart beats for almost full magnetization recovery. Therefore, it is possible to acquire a low flip angle readout reference image during alternate heart beats without increasing the breath-hold duration or decreasing the T1 contrast of desired IR image. Phase sensitive cardiac imaging poses unique challenges due to the combination of field inhomogeneity, motion, and low SNR, which make it difficult to obtain a reliable estimate of the background phase and B_1-maps. The approach we have taken is use the reference image acquired at the same cardiac phase, during the same breath-hold acquisition during alternate heart beats to estimate both the background phase and surface coil field maps. This type of acquisition provides a reference image with good spatial resolution and eliminates mis-registration errors due to motion.

All experiments were conducted using a Siemens Sonata 1.5T MR imaging system. Imaging was performed during diastasis (prior to atrial filling) using a gated segmented acquisition of *k*-space over several heartbeats during a single breath-hold. A true-FISP 3d sequence using a 192x86x10 acquisition matrix for both IR and reference resulted in an imaging duration of 130ms per heartbeat for 20 heartbeats total duration including the reference. Longer acquisition windows acquiring higher spatial resolution is possible. The phase and partition encode ordering was sequential with all phase encodes acquired each heartbeat for a given partition encode. The T1-weighted IR image was acquired using a 50° flip angle, while the reference used a 8° flip angle.

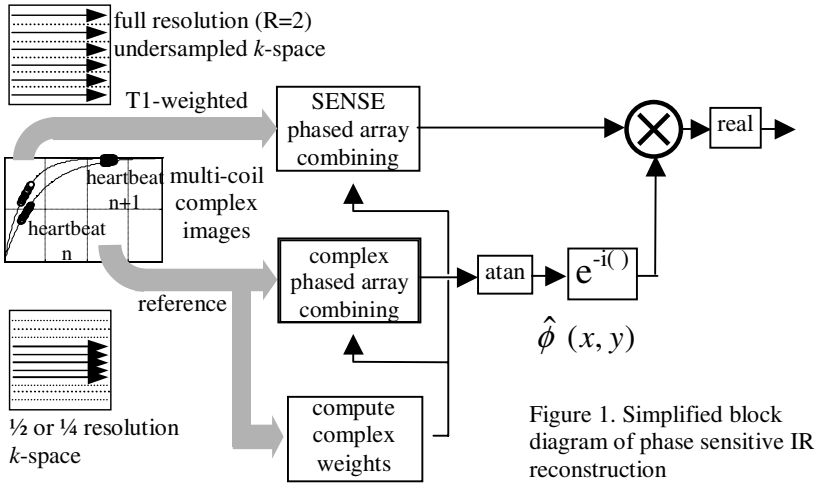

Figure 1. Simplified block diagram of phase sensitive IR reconstruction

A simplified block diagram of the phase sensitive SENSE reconstruction is shown in Fig. 1. The T1-weighted IR images were acquired with phase encodes corresponding to FOV/2 spacing, and reconstructed to obtain the full FOV. The reference image was acquired with the same number of phase encoding steps using full-Fourier k-space sampling over the full FOV (or 2x FOV for no-wrap). Thus the spatial resolution of the reference image was approximately ½ the spatial resolution of the IR image (or ¼ for no-wrap reference). The B_1-maps derived from the reference images were used for optimal B_1-weighted combining [3] to form a complex reference image, and for SENSE processing [1] to form the full FOV IR image.

Images were acquired from animal studies with infarct, as well as normal volunteer studies. For the results shown, images were acquired using a 5-element surface coil array for the pig study and 8-element array for the human subject. The FOV was 300x178 mm^2 for the pig study and 350x263 mm^2 for the volunteer study corresponding to an in-plane resolution of 1.56x2 mm^2 and 1.8x3 mm^2, respectively. In the partition encode dimension, 8 slices spaced 8mm were reconstructed from 10 partition encodes, which may be 2x interpolated to 16 slices with 4mm spacing. Images were acquired between 10 and 20 minutes after administering a single dose (0.1 mmol/kg) of contrast agent (Gadopentetate Dimeglumine, Berlex Magnevist). The TI time was set to approximately null the normal myocardium. The use of phase sensitive detection avoids the need to precisely null the normal tissue as is common practice with IR using magnitude detection.

Results

Example images are shown in Figures 2 and 3 for the normal volunteer and pig with infarcted myocardium, respectively. The acquisitions were 15s and 11s, corresponding to 20 heartbeats at heart rates of 80 and 110 bpm, respectively. The SENSE reconstruction is effective in suppressing aliasing with no evident artifacts, and phase sensitive reconstruction has restored the correct polarity.

Discussion

Parallel imaging using SENSE has been used for single breath-hold 3d phase sensitive IR imaging of myocardial infarction. Using SENSE with true-FISP imaging, the 3d acquisition is accomplished with 2 R-R between inversion pulses, as well as using full-Fourier acquisition. Using 2 R-R between inversions leads to almost full magnetization recovery thus improving CNR and reducing sensitivity to R-R timing variation. Full-Fourier phase sensitive IR has an improved point spread function [2] as compared with methods using partial-Fourier acquisition [4] that lead to artifacts. Phase sensitive reconstruction has the additional benefit of TI insensitivity.

References

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[3] Roemer, PB, et al., *MRM*. 16, 192-225, 1990.

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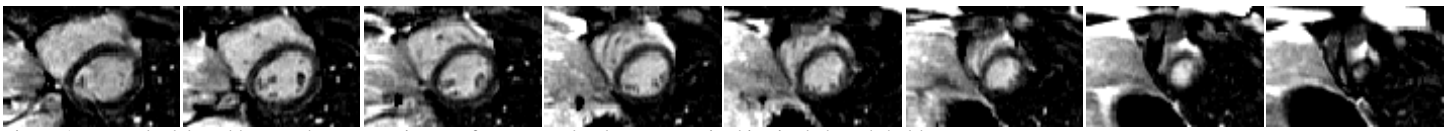

Figure 1. Example delayed hyperenhancement images from normal volunteer acquired in single breath-hold.

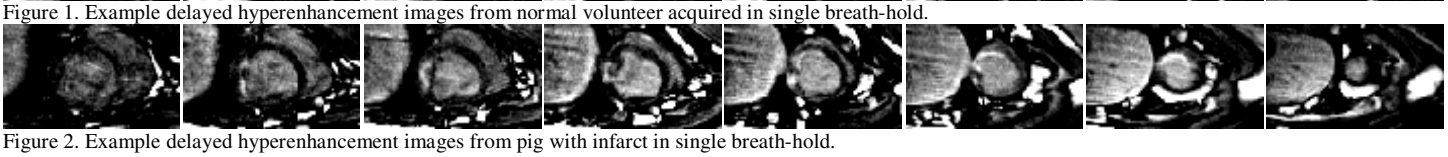

Figure 2. Example delayed hyperenhancement images from pig with infarct in single breath-hold.