

Accelerated Phase Sensitive Inversion Recovery for Detecting Myocardial Infarction using Gd-DTPA Delayed Hyperenhancement

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Abstract

Following administration of gadolinium, infarcted myocardium exhibits delayed hyperenhancement and can be imaged using an inversion recovery (IR) gradient recalled echo sequence. Phase sensitive reconstructed IR has a number of benefits [1] 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. The imaging time may be accelerated by acquiring fewer phase encodes using partial-Fourier and/or sensitivity encoding (SENSE [2]) methods. We present and compare experimental results for both methods. The acceleration may be used to either reduce breath-hold duration or increase spatial resolution for a fixed breath-hold time.

Methods

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. The approach we have taken is to obtain a background reference image at the same cardiac phase, during the same breath-hold acquisition. Using Gd-DTPA, the inversion recovery acquisition sequence requires 2 heart beats for almost full magnetization recovery. Therefore, it is possible to acquire the reference image during alternate heart beats without increasing the breath-hold duration. This type of acquisition provides a reference image with high spatial resolution and eliminates mis-registration errors due to motion. The reference image is used to estimate both the background phase and surface coil field maps.

All experiments were conducted using a GE Signa CVi 1.5T MR imaging system. For each slice, imaging was performed during diastasis (prior to atrial filling) using a prospectively gated segmented acquisition of k -space over several heartbeats during a single breath-hold. Images were acquired using a 4-element cardiac phased array. A fast gradient recalled echo pulse sequence was used with interleaved phase encode ordering. Imaging of a single short axis slice was performed during each breath-hold using the following parameters: bandwidth ± 31.25 kHz, TE=3.4 msec, TR=7.8 msec, and 8 mm slice thickness. The T1-weighted IR image was acquired using a 20° flip angle, while the reference used a 5° flip angle. A chemical shift based fat saturation was performed prior to readout.

For non-accelerated imaging, the typical FOV was 360mm x 270mm with an image matrix of 256x96, thus the in-plane spatial resolution was approximately 1.4×2.8 mm². The 96 phase encodes were acquired in 12 heartbeats using 16 views per segment with 2 heartbeats between inversion pulses. Accelerated imaging using SENSE, the images were acquired with either 96 (12 heartbeat breath-hold) or 48 (6 heartbeat breath-hold) phase encodes corresponding to FOV/2 spacing, and reconstructed to obtain a full FOV with a matrix size of 256x192 (1.4×1.4 mm²) or 256x96 (1.4×2.8 mm²), respectively. For partial-Fourier (5/8 NEX) acquisition, images were acquired using either 96 or 48 phase encodes, with 12 and 6 lines of overscan, respectively. In each case, the reference image was acquired with the same number of phase encoding steps over a full FOV and using full-Fourier k -space sampling. Thus the spatial resolution of the reference image was approximately $\frac{1}{2}$ the spatial resolution of the IR image.

The surface coil field maps derived from the reference images were used for optimal B1-weighted combining [3], and for SENSE processing [2] in the case of reduced FOV acquisitions. By applying the same B1-weighted complex combining to both T1-weighted IR and reference image, any phase error in the B1-maps was cancelled in the phase sensitive (homodyne) image. All images were surface coil intensity normalized based on the reference magnitude image.

Images were acquired from patients with suspected coronary artery disease under two clinical research protocols approved by the Institutional Review Board of the National Heart, Lung, and Blood Institute, with prior informed consent. Both the SENSE and partial-NEX methods were used for 7 patients with MI; the SENSE method was used with 5 additional patients without MI. Images were acquired between 10 and 30 minutes after administering a double dose (0.2 mmol/kg) of contrast agent (Gadopentetate Dimeglumine, Berlex Magnevist). A short axis slice was

imaged for each method using a TI time 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

A single slice, short axis image of the heart from a patient with an anterior MI is shown in Figure 1. The images were acquired with 96 phase encodes (top row) and 48 phase encodes (bottom row), corresponding to 12 and 6 heart beat acquisitions, respectively. The left column is acquired at full-FOV, the middle column is acquired at FOV/2 and uses SENSE reconstruction, and the right column uses partial-NEX. All images are phase sensitive reconstructions. A myocardial infarct along the anterior wall is clearly hyperenhanced in this image. Note that the quality of the SENSE (e) and partial-NEX (f) images, acquired with approximately $\frac{1}{2}$ the breath-hold duration as conventional acquired image (a), have comparable quality and are artifact free. Note also that the SENSE (b) and partial-NEX (c) images, acquired with the same breath-hold duration as conventional acquired image (a), achieve higher spatial resolution, albeit with increased noise as predicted. Individual images were acquired during separate breath-hold.

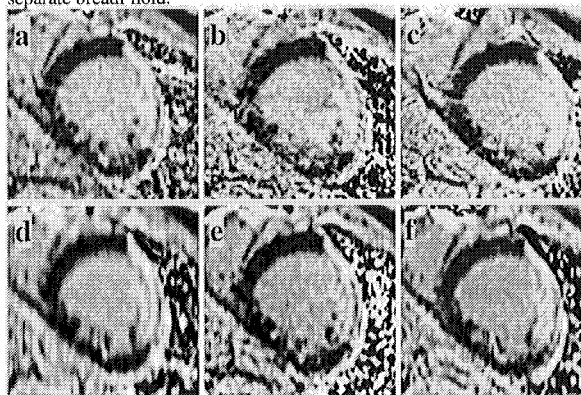


Figure 1. Short axis images of heart with Anterior MI.

Discussion

We have demonstrated accelerated phase sensitive IR for detecting MI using Gd-DTPA delayed hyperenhancement using both partial-NEX and SENSE methods. Accelerated imaging may be used to decrease the breath-hold or increase the spatial resolution up to a factor of 2 with the parameters used. The spatial resolution of the reference image used for the phase map was approximately $\frac{1}{2}$ the full resolution of the IR image. Homodyne artifacts due to errors in the phase map were not observed with the reference spatial resolution used. The SENSE method (R=2) required only a single wrap within the FOV, which complicated the localization procedure and reduced the effective acceleration factor, as compared to imaging which tolerated wrap outside the heart region of interest. This is particularly difficult to achieve with long axis views. With additional coils, it may be possible to allow additional wrap with reasonable performance. The partial-NEX method tolerates wrap outside the region-of-interest, and is therefore simpler to use. Additionally, the SENSE method has a SNR penalty of approximately 20% (using 4 coils) as compared to partial-NEX, due to the inherent noise amplification described by the SENSE g-factor [2].

References

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