Surface Coil Intensity Correction for Phase Sensitive Inversion Recovery Delayed Enhancement of Myocardial Infarction Improves Image Appearance

P. Kellman[1] and A. E. Arai[1]
[1]NHLBI/NIH, Bethesda, MD, United States

Introduction

Surface coil intensity correction of delayed enhancement (DE) images is important for accurate MI sizing using full-width half maximum methods to mitigate partial volume effects [1]. Furthermore, surface coil intensity correction is an important adjunct to phase sensitive inversion recovery (PSIR) delayed enhancement imaging. PSIR delayed enhancement [2] has demonstrated a number of benefits including consistent contrast and appearance over a relatively wide range of inversion recovery times (TI), improved contrast-to-noise ratio (CNR), and accurate depiction of the enhanced region. Measurement of the infarct size becomes independent of TI [2-4]. PSIR may also have fewer artifacts [5] and reduced edge enhancement due to improved real point spread function [2]. Surface coil intensity correction facilitates restrospective nulling of tissue by simple adjustment of the window-level.

Previously described surface coil intensity correction relied on normalization using a high spatial resolution proton density (PD) image acquired at low flip angle during alternate heartbeats [2]. A relatively simple normalization by division led to noise amplification in noise only regions. This "salt and pepper" appearance while outside the region of interest has hindered the acceptance of this method. An improved method using region filling without reducing the spatial resolution of the reference is demonstrated to provide excellent quality images with normal appearance in noise regions.

Methods

Delayed enhancement images were acquired 15-20 min following administration of Gd-DTPA (0.2 mmol/kg) using an IR-turboFLASH sequence. For each slice, imaging was performed in mid-diastole using a prospectively gated segmented acquisition of k-space over several heartbeats during a single breath-hold. Inversion recovery pulses were applied every other heartbeat to permit nearly full recovery of magnetization in the presence of Gd-DTPA, thereby minimizing sensitivity to heart rate variation. A PD reference image used to estimate background phase and for surface coil correction. The PD image was acquired during the same breath-hold and cardiac phase in alternate heartbeats using a reduced flip angle readout. In this manner, both the IR and PD image are spatially registered, avoiding errors due to respiratory and cardiac motion.

PSIR image reconstruction was performed off-line using custom software written in Matlab as previously described [2] with the exception of surface coil correction which used a modified method. The PD reference image was thresholded to create a binary mask which had value 1 in noise only regions. The PD reference was reconstructed in SNR units [6] which facilitated use of a fixed threshold value. The Matlab roifill function was uses to calculate intensity values to fill the noise regions. The roifill function detects the perimeter pixels from the binary mask, and calculates the intensities within the mask regions by solving the Laplace equation using the intensity of the PD image at the perimeter pixels as boundary conditions. In this way, the noise only regions are filled with non-zero values with a smooth spatial distribution. The PD reference with modified noise regions is used for surface coil correction of the PSIR image, thus avoiding excessive noise amplication. Importantly, the PD reference image was not modified outside the noise regions, thereby maintaining the accuracy of the PD reference image.

Delayed enhancement imaging was performed on patients with suspected coronary artery disease (CAD). Images were reconstructed using the proposed method for surface coil correction, as well as previous simpler method for comparison. Images were processed for N=20 patients.

Results

Surface coil intensity corrected images (Fig. 1) using the proposed method corrected for surface coil variation while maintained the desired normal appearance in noise only regions. The previous described simpler method had the salt and pepper appearance in non-tissue regions which also made window and leveling easier more difficult.

Discussion

Surface coil intensity correction is important for accurate MI sizing, and combined with PSIR delayed enhancement provides a clinically robust means of nulling normal myocardium across the entire heart. Simple normalization by division with a PD reference is an effective method but leads to high apparent noise in non-tissue regions thus altering the image appearance. The proposed region filling method provides a high quality surface coil intensity correction while reliably maintaining a normal image appearance. Methods such as polynomial surface fitting were found to be less accurate and less reliable, particular in cases of wrap artifacts.

References

[1] Hsu LY, et al., JMRI. 2006 Mar;23(3):298-308.
[2] Kellman P, et al., MRM. 2002 Feb;47(2):372-83.
[3] Setser RM, et al., JMRI. 2005 May;21(5):650-5.
[4] Huber RM, et al., Radiology. 2005 Dec;237(3):854-60.
[5] Kellman P, et al., MRM. 2004 Feb;51(2):408-12.
[6] Kellman P. et al., MRM 2005 Dec;54(6):1439-47.

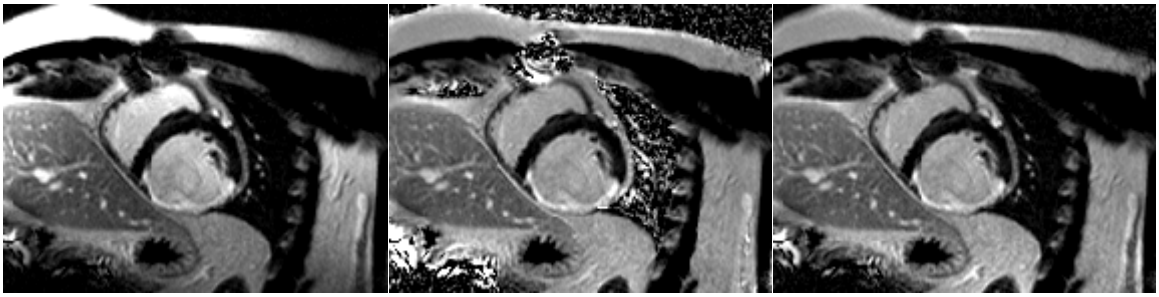

Fig 1. PSIR delayed enhancement images for chronic MI patient: without surface coil intensity correction (left), simple correction (center), improved surface coil intensity correction (right). Note that improved surface coil correction method improves image appearance by reducing noise amplification in air regions.