Improved Susceptibility-Weighted Imaging of Reperfusion Intramyocardial Hemorrhage with Multiple-echo Image Combination

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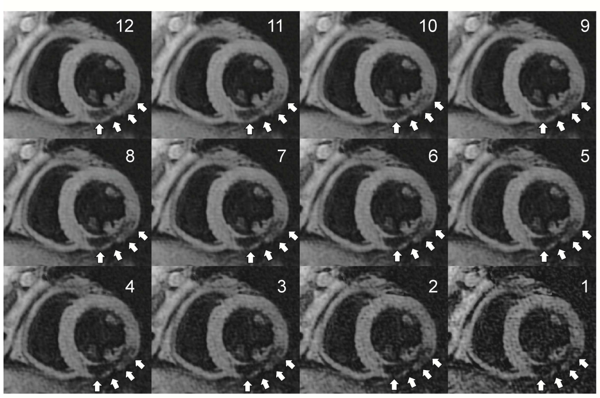
Purpose: To compare single-echo and a novel multiple-echo image combination using source or susceptibility weighted images for improvements in image quality assessed quantitatively through intramyocardial hemorrhage contrast and signal-difference-to-noise measurements.

Introduction: Reperfusion of ischemic myocardium can lead to interstitial hemorrhage which is associated with microvascular obstruction and adverse clinical outcomes. MR imaging has been shown to be feasible in depicting hemorrhagic infarcts with spoiled gradient-echo imaging. Long TE source images or post-processed susceptibility-weighted imaging (SWI), a new means to enhance contrast in MR imaging using phase information from long TE images(1), can both provide excellent hemorrhagic contrast. Unfortunately, several imaging constraints such as long TE, high pixel bandwidth and image acquisition times related to cardiac and respiratory motion lead to relatively low signal-to-noise (SNR) images. An SNR improvement can be achieved by averaging images acquired at consecutive TEs, either source images or SWI (combined magnitude and phase images) (2). In this study we used averaging of echoes to provide a single improved image and studied the image quality to determine a best image reconstruction protocol.

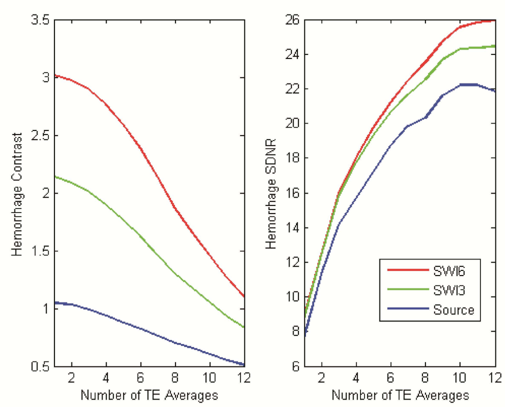
Materials and Methods: Eleven myocardial infarction subjects at were studied at 3 days after infarction. A dark blood double inversion recovery multiple-gradient echo sequence (flip angle = 20 degrees; repetition time, 20 ms; 12 echo times, 2.4-15.5 ms (1.2 ms spacing); in-plane spatial resolution, 2.5 x 1.7 mm2, bandwidth = 2005 Hz/pixel, breath-hold duration=15 heartbeats) was used for T2* weighted multi-echo imaging at 1.5T. Raw k-space data were saved to the scanners hard disk and transferred to a personal computer. Filtered phase images were reconstructed using Matlab R2009b (Mathworks, Natick, MA) from saved raw data files for both long and short axis images. High-pass filtered phase images for each echo time were reconstructed by first reconstructing a complex low pass image using a 64 point hanning filter and unfiltered complex image. High-pass filtered phase images were then calculated by dividing the low pass filtered image into the unfiltered image and then extracting the phase component. SWI images for each TE were constructed with 3 and 6 phase mask multiplications. Echo-combination was done by averaging 2 to 12 of the longer TE SWI or source images to create a single echo-combined image.

Average signal intensity was measured from identical region-of-interests for each reconstruction in the hemorrhagic infarct (identified as a hypointense lesion) and adjacent myocardium. The noise standard deviation was estimated from an ROI without signal (either outside of the body or in the lung cavity). Contrast and signal-difference-to-noise (SDNR) were calculated from these measurements for source images, SWI images and multiple-echo combined images.

Results: There were 4/11 patients with hemorrhagic infarcts. A representative example of SWI6 echo-combination is shown below. There was a three-fold increase in contrast with SWI compared to source images. Contrast increased significantly when comparing 6 vs 3 phase mask multiplications. Contrast decreased and signal-to-noise increased with increased echo-combination. SDNR increased with echo-combination up to 10 averages (graph below).



Susceptibility-weighted images with 1-12 echo averages demonstrate increased SNR and decreased contrast in the inferior hemorrhagic myocardial infarct with greater echo combination.



ROI analysis from all patients shows increased contrast with SWI vs source images and increased SDNR (up to 10 echoes) with more echo combinations at the expense of decreased contrast. SWI3 and SWI6 = SWI with 3 and 6 phase mask multiplies, respectively.

Conclusions: SWI with echo-combination is an effective means of generating high quality images of left ventricular myocardium for tissue characterization. Hypo-intense lesions correlated with areas of acute myocardial infarction and dark core regions at LGE imaging. Echo-combination of source or SWI images increases SNR at the cost of hemorrhage contrast. SWI with six phase mask multiplications and 10 echo averages provides optimal image SDNR and contrast. Image quality of echo-combined SWI is superior to source, SWI and echo-combined source images.

[1] Haacke EM et al. “Susceptibility weighted imaging (SWI)” Magn Reson Med;52(3):612-8, 2004. [2] Quinn M.P. et al. “Comparison of Multiecho Postprocessing Schemes for SWI with Use of Linear and Nonlinear Mask Functions.” AJNR (2013); doi: 10.3174/ajnr.A3584.