Accelerated Delayed Enhancement Imaging with Through-Time Radial GRAPPA

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Target Audience: Clinicians who are interested in myocardial infarction and viability imaging.

Purpose: The assessment of myocardial infarction (MI) and tissue viability is of utmost clinical importance, and delayed contrast enhancement (DCE) imaging is a well-accepted standard [1]. Inversion-recovery (IR) is typically utilized to reveal scarred myocardium as these regions are hyper-enhanced due to T1 contrast upon injection of Gd-DTPA. Capturing the mid-diastolic interval, when the blood and myocardium are relatively stationary, is desired. To capture this rather short period, segmented k-space coverage is commonly used, which requires data collection over several heartbeats to reconstruct an image [2]. Recently, a Cartesian single-shot bSSFP sequence technique [3], has been used to enable free-breathing DCE imaging; however, spatial resolution is traded for acquisition speed, and multiple heartbeats may still be required to increase SNR [4]. Alternatively, higher degrees of acceleration can be achieved by using undersampled radial trajectories [5], such that data acquired during mid-diastole in a single heartbeat can be used to generate a higher SNR image. In this work, we aim to show the feasibility of IR-DCE imaging using highly undersampled radial trajectories with reconstruction using through-time radial GRAPPA [5] with or without multiple heartbeats.

Methods: Under ACUC approval, one swine with antero-septal MI was imaged at 1.5T (Avanto, Siemens Medical Systems, Erlangen, Germany) using the standard body and spine coils (15 receiver channels). A single dose of gadopentetate dimeglumine was administrated 15-20 min before the imaging protocol. Cardiac imaging was performed using a radial ECG-triggered IR-gradient-echo sequence (FOV: 200 mm, resolution: 1.56x1.56x7.0 mm^3, TR: 4.4 ms, BW: 797 Hz/pix). Inversion time was varied between 250-350 ms. 8-fold acceleration rate (R = 8) was achieved by undersampling the radial trajectory in the azimuthal direction. 16 radial spokes were acquired per image (temporal resolution: 70 ms) with no view-sharing applied. Through-time radial GRAPPA was utilized to reconstruct images from the undersampled k-space. In order to calibrate the GRAPPA weights, 50 fully-sampled (128 spokes) gradient-echo reference images were acquired under free-breathing without gating prior to the accelerated IR-DCE imaging. Image reconstruction was carried out on a remote server with multi-CPUs and a GPU that enabled low-latency reconstructions with real-time inline display [6]. Both short axis and long axis views were acquired under several seconds of breath-holding. Subsequently, images captured in single heartbeats were compared to images reconstructed after k-space averaging over 4 heartbeats.

Results: As shown in Figure 1, the MI on the left ventricle (LV) is easily detectible with adequate contrast between the normal myocardium (dark) and the infarct (bright). Even though images from single heartbeats appear noisier compared to images that are averaged over multiple heartbeats, the infracted region is still visible and well-delineated due to the improved temporal footprint of the accelerated radial sequence.

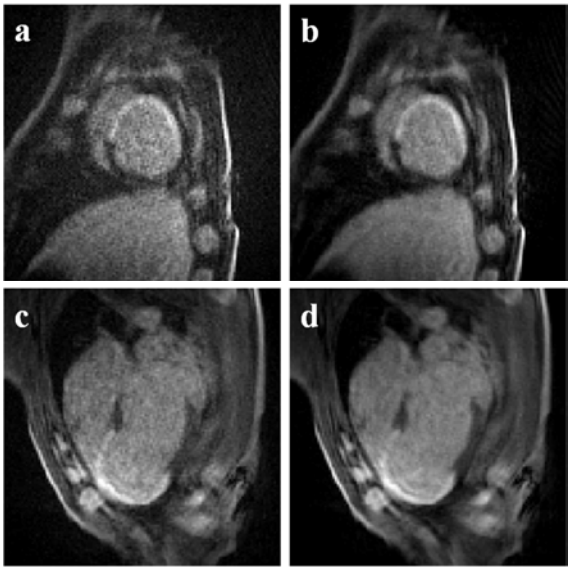

Figure 1: DCE images of a swine heart with a chronic apical myocardial infarction in mid-diastole. Top: Short-axis view. Bottom: Long-axis view. Left: Images captured in a single heartbeat. Right: Images after averaging over 4 heartbeats.

Discussion: This accelerated delayed enhancement imaging technique could also be used with an IR-prepared trueFISP sequence to increase SNR and imaging speed. It could be utilized by a phase-sensitive-inversion-recovery sequence (PSIR) as well to achieve higher contrast-to-noise-ratio (CNR). Additionally, it may be possible to generate single heartbeat IR-DCE images without using breathholding at all, given the high SNR and contrast seen in the single heartbeat images shown in Figure 1a and 1c.

Conclusion: Delayed contrast enhancement imaging with improved temporal and spatial resolution while maintaining contrast is demonstrated via high rates of radial undersampling and through-time radial GRAPPA reconstructions. Accelerated radial imaging that can deliver single heartbeat high-resolution DCE images, will likely advance viability imaging by avoiding breath-holding or complicated motion-correction techniques.

References: [1]Saraste et al., *J Nucl Cardiol* 2008; [2]Kellman et al., *Magn Reson Med* 2002; [3]Huber et al., *Invest Radiol* 2006; [4]Ledesma-Carbayo et al., *J Magn Reson Imaging* 2007; [5]Seiberlich et al., *Magn Reson Med* 2011. [6]Saybasili et al., *ISMRM* 2012. **Funding:** Siemens, NIH/NIBIB R00EB011527.