A real-time cine late gadolinium enhancement imaging method at 3T

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Introduction
A real-time Late Gadolinium Enhancement (LGE) MRI technique (free breathing and non-gated) is presented for detection of myocardial scars. Conventional LGE imaging methods currently in use are applied in conjunction with breath-hold and, thus, are difficult to use in patients with cardiac disease and commonly lead to motion artifacts. Additionally, conventional techniques involve ECG gating, which is problematic in patients with arrhythmias requiring multiple breath holds and arrhythmia rejection. Real-time LGE imaging obviates these difficulties and can, in principle, acquire cine images to assess wall motion over several heart phases as part of the same scan. The main limitation of real-time LGE imaging is long acquisition window and low temporal resolution. These limitations lead to temporal blurring of wall motion and possible overestimation of infarct size. In addition, accurate timing parameters for acquisition of an image with completely nulled myocardium can be difficult. The goal of this study was to increase the temporal resolution of real-time, cine LGE imaging, providing the possibility for better visualization of the wall motion and more accurate assessment of myocardial viability.

Method
Imaging was performed on a 3T scanner using a 16 channel phased array coil (Achieva TX, Philips Healthcare, Best, NL). Two types of studies were performed. Firstly, in a phantom with heterogeneous T1, a series of T1-weighted images were collected to show the sensitivity of the proposed sequence to T1 variations similar to both normal and infarcted myocardium. Secondly, a series of images were collected in a normal volunteer to assess visualization of cardiac wall motion and achievable temporal resolution.
Several single-shot images were acquired using an inversion-recovery TFE-EPI sequence with EPI factor=7 and TFE factor=14. The images were acquired similar to previous studies [1-2] with the following parameters: FOV= 250x340, matrix size= 120x160, TR/TE= 5.7/1.9 ms, flip angle= 25 deg., spatial resolution= 2x2x8 mm, 75% k-space acquisition in the phase encode direction. SENSE parallel imaging (acceleration factor = 1.7) was employed to reduce the acquisition window. The achieved acquisition window was about 80 ms, permitting collection of 12 cine frames in one heartbeat (with a heart rate of about 60 bpm). With view-sharing, it should be possible to increase the number of frames to over 20 frames per cardiac cycle. Although images were acquired continuously after the inversion pulse and accurate calculation of TI was no longer necessary, the TI for complete myocardial nulling will depend on the length of acquisition window. To compensate, three dynamic scans were obtained consecutively, and for each dynamic scan, the trigger delay after inversion pulse was increased by approximately 20 ms. Additionally, the three dynamic scans were each repeated 5 times in order to ensure that at least one LGE image was collected near a more conventional mid-diastolic cardiac phase. In total, the resulting imaging time was about 15 sec resulting from 3 dynamic scans and 5 repetitions for a total of 15 cine LGE data sets.

Results
Figure 1 shows images of conical tubes with different concentrations of Gd-DTPA. The spatio-temporal intensity variations of the tubes in different phases show the potential capability of this technique to distinguish between different tissues in the human heart. Tubes number 6 and number 8 have T1 values corresponding to the normal and infracted myocardium, respectively. As illustrated, there is no need to manually calculate TI in this method as the image displaying the highest contrast between the normal and infracted myocardium is immediately recognizable (e.g., phase 2, dynamic scan 1 in the phantom).
Figure 2 shows 12 phases acquired in one cardiac cycle in a normal volunteer. The number of acquired images, collected in one cardiac cycle, is more than twice the number in previously published methods (in [1,2] the maximum number of acquired phases was 5). With 12 phases, wall motion can now be analyzed with a higher accuracy. In comparison to conventional cine images for assessment of wall motion collected over many cardiac cycles, the real-time method discussed here has acceptable spatial and temporal resolutions and, thus, the sequence may potentially be utilized for real-time Cine imaging (with or without the inversion pulse) as well.

Conclusion
The present study demonstrates a novel approach to real-time LGE MRI, permitting acquisition of 12 cardiac phases in a single heart beat. Unlike other methods, images were acquired before, during, and after the specified TI time. This leads to better depiction of the wall motion and in addition should lead to better estimation of infarct transmurality. The temporal resolution achieved should permit improved assessment of wall motion directly from LGE images and provides requisite spatio-temporal contrast for rapid assessment of viability. The main limitation of previously proposed real-time LGE methods was the large acquisition window and low temporal resolution. The proposed method resolves this limitation by reducing the length of the acquisition window, thereby increasing the temporal resolution. To further improve the temporal resolution, view-sharing could be used. The temporal resolution achieved using this method allows for the image with nulled- myocardium to be acquired without the need to set a value for TI. The free-breathing scan time to collect all 15 cine LGE data sets is about 15 seconds which is sufficiently short to be comfortable even in the case of the very sick of patients.

References
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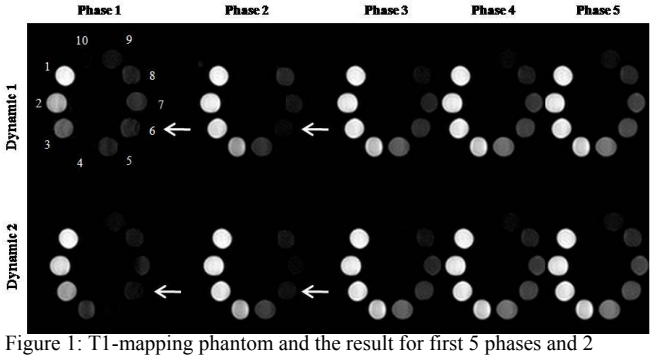

Figure 1: T1-mapping phantom and the result for first 5 phases and 2 cine dynamic scans. Arrows point to the tube corresponding to T1 value similar to those of normal myocardium

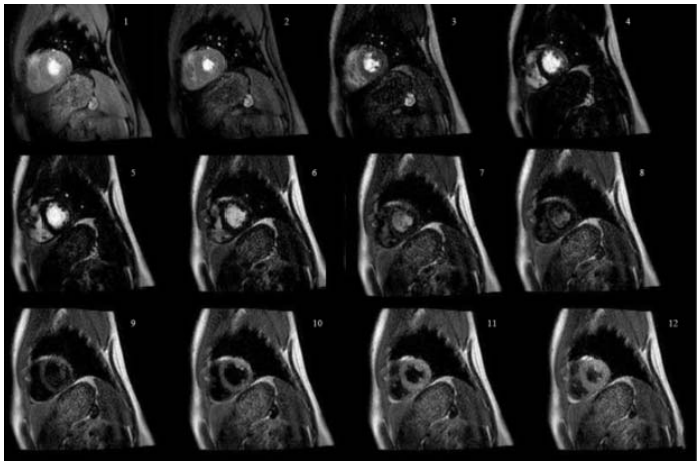
Figure 2: Real-time LGE imaging in a 29 years old normal volunteer achieving frames in 12 cardiac phases within a single heart beat. Image 5 shows the image with nulled- myocardium.