Cine Delayed Enhancement Imaging of the Heart

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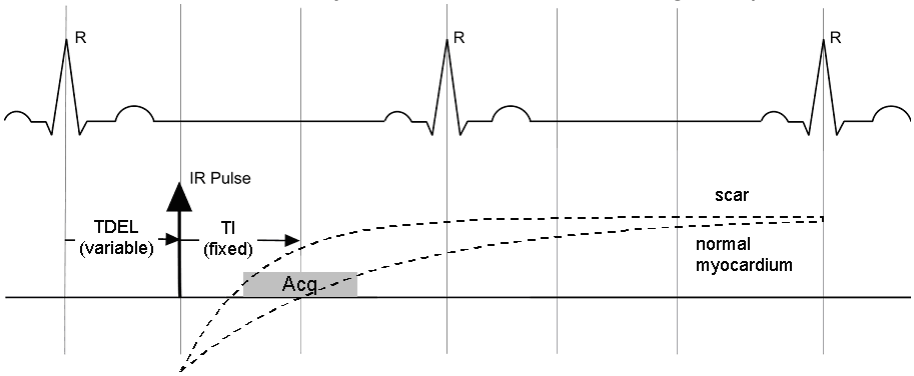
Introduction: Magnetic resonance imaging (MRI) can be used to accurately assess left ventricular (LV) wall motion, as well as the extent of non-viable myocardium, during a single examination. However, using existing techniques these data must be acquired separately, requiring multiple image acquisitions. Furthermore, interpretation can be hampered by the need to mentally integrate wall motion and viability information from separate, potentially misregistered image series.

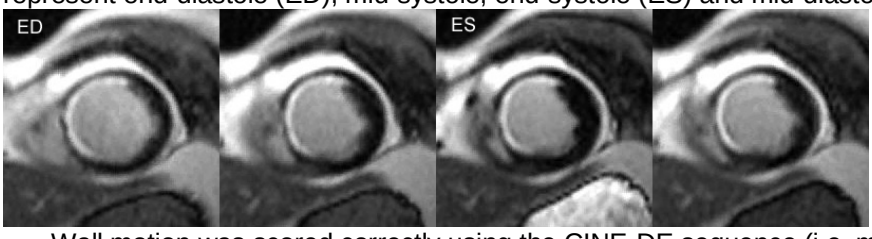
Purpose: To describe and provide preliminary clinical validation for a novel cine delayed enhancement (CINE-DE) pulse sequence, which permits simultaneous visualization of wall motion and myocardial scar extent in a single acquisition.

Methods: The CINE-DE technique is based on inversion recovery (IR), single-shot, balanced steady state free procession (TrueFISP) imaging. As shown in the figure at right, each frame of the cine series is acquired during a separate RR-interval using a constant inversion time (TI). However, the trigger delay (TDEL) is varied between images, resulting in a series of single-shot images, each from a different phase of the cardiac cycle. Images are acquired every other heart beat. The sequence has been implemented on a 1.5T MAGNETOM Sonata scanner (Siemens, Erlangen, Germany) using the following typical acquisition parameters: α 50°, TR 2.5 ms, TE 1.1 ms, BW 1090 Hz/pixel, FOV 380 mm, RFOV 75%, acquisition matrix 192 x 115 (frequency, phase). 15 image frames are acquired in each cine, with a variable temporal spacing to cover the cardiac cycle. Each cine series is acquired during a single breath-hold.



CINE-DE images were acquired in 25 patients undergoing clinical assessment of myocardial viability, 10-20 minutes after intravenous injection of 40 ml of 0.5 mmol/ml gadopentetate dimeglumine (Magnevist, Berlex Imaging, Wayne NJ), using an IRB approved protocol with waiver of individual consent. In the first 15 patients, image planes (long-axis or short-axis) were acquired in order to best visualize myocardial scar in the individual patient. In the remaining 10 patients, mid-ventricular (n=9) or basal (n=1) short-axis images were acquired to facilitate comparison with other image types. As part of the clinical protocol, TrueFISP cine images were acquired in each patient to assess regional LV wall motion, at anatomic levels matching the CINE-DE images. Also, standard delayed enhancement images (DE-TFL) were acquired using an IR TurboFLASH acquisition to visualize the presence of non-viable LV myocardium. A single reader evaluated separately the CINE-DE images for both wall motion and scar extent, corresponding cine images for wall motion, and DE-TFL images for the extent of myocardial scar. In all cases, the reader was blinded to other imaging results during analysis. For each image type, three myocardial segments were evaluated per short-axis slice, representing the LAD, LCX and RCA coronary territories. Segmental wall motion was graded as follows: normal (0), hypokinetic (1), akinetic/dyskinetic (2). Scar extent was graded as follows: no scar (0), 1-25% scar (1), 26-50% scar (2), 51-75% scar (3), 76-100% scar (4).

Results: Breath-hold duration varied from 18-25 seconds, depending on heart rate; temporal spacing of images averaged 62 $\pm$ 10 msec. Images from a single patient with chronic ischemic heart disease are shown below; from left, the images represent end-diastole (ED), mid-systole, end-systole (ES) and mid-diastole. No scar was visible in 4 of 25 patients (16%), a finding verified by DE-TFL imaging. In patients with visible non-viable myocardium, contrast was consistent throughout each cine; the average ratio of non-viable to viable image intensity was 7.2 $\pm$ 3.1; the average ratio of non-viable to blood pool image intensity was 1.7 $\pm$ 0.7.



Wall motion was scored correctly using the CINE-DE sequence (i.e. matched cine results) in 21/30 segments (70%) and differed by $\pm$1 in 9/30 segments (30%). Similarly, scar extent was graded correctly using the CINE-DE sequence (i.e. matched DE-TFL results) in 21/30 segments (70%) and differed by $\pm$1 in 9/30 segments (30%).

Discussion/Conclusions: Cine delayed enhancement imaging is a promising technique for simultaneous visualization of both wall motion and myocardial scar extent. Efforts are currently underway to improve the temporal resolution of the sequence (from ~285 msec) by incorporating parallel imaging and/or segmented k-space schemes.