Heart rate adaptive inversion preparation and fat suppression for late gadolinium enhancement

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Target audience: Clinicians and physicists in cardiac MRI desiring robust fat-suppressed late gadolinium enhancement (LGE).

Purpose: LGE allows imaging of infarction and cardiomyopathies by measuring the accumulation of contrast agent within the myocardium with an inversion (IR) prepared sequence. Epicardial enhancement can be poorly visualized in the presence of pericardial fat because both fat and enhancement appear as bright signal. One previous approach to fat-suppressed LGE was using two appropriately timed fat-selective RF pulses which re-invert and invert fat signal[1,2] but this technique was sensitive to heart rate variations. The goals of the present work are (1) to make fat-suppressed LGE robust against heart rate variations through heart rate adaptive timing of all IR pulses and (2) increase B_0 robustness through asymmetric adiabatic RF pulse design.

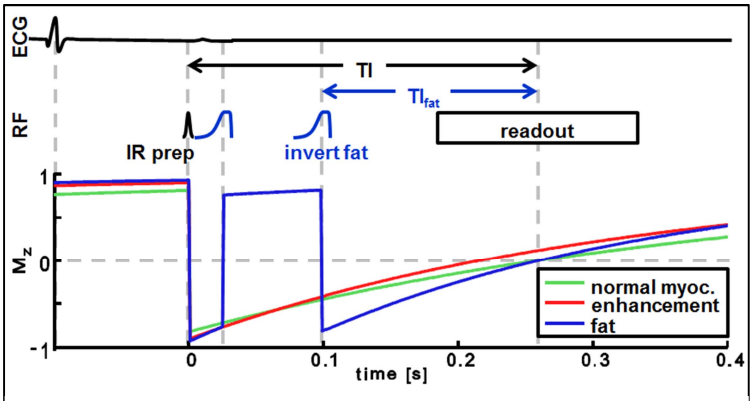

Fig. 1: *Timing diagram of cardiac gated IR prepared fat suppression pulse sequence and possible M_z signal evolution. Signal from normal myocardium is nulled by dynamic timing of TI and signal from fat is nulled by dynamic timing of TI_{fat} which makes this method robust against heart rate variations.*

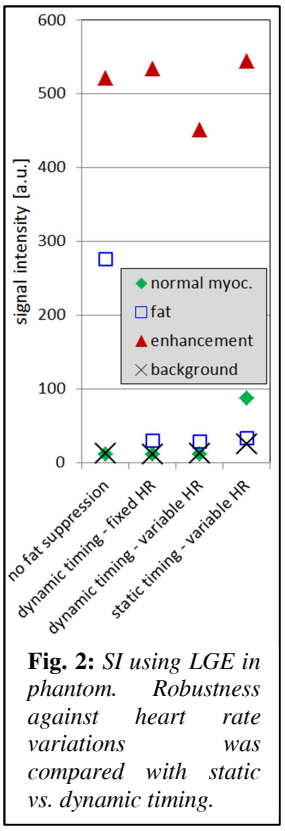

Fig. 2: *SI using LGE in phantom. Robustness against heart rate variations was compared with static vs. dynamic timing.*

Methods: M_z magnetization depends on the repetition time of the IR pulse and therefore in cardiac gated sequences depends on the patient heart rate. Heart rate variation leads to a shifting of the inversion times (TI and TI_{fat}) at which the myocardial and fat signals are nulled. Therefore a heart rate independent IR preparation and fat suppression scheme was developed by measuring the length of each R-R interval during the scan and adaptively time-shifting all IR pulses accordingly (Fig. 1). Furthermore, the selectivity of fat-selective pulses was improved by designing an asymmetric adiabatic inversion pulse[3] based on HS1 and tanh/tan. This pulse had a 2 times narrower transition width of 87Hz compared to HS1 (10µT $B_{1,max}$ and 40ms pulse duration).

The method was tested in 6 volunteers without contrast and 30 patients with contrast on 1.5T and 3.0T GE Healthcare MR systems. The $T_{1,fat}$ value which influences the heart rate-dependent TI_{fat} was calibrated in healthy volunteers at field strengths 1.5T (220ms) and 3.0T (300ms). Signal intensity (SI) was measured in a phantom with fat and two water substances with T_1 = 0.2s and 1.1s, mimicking enhanced tissue and normal myocardium, respectively. For testing robustness against heart rate variations the ECG trigger of phantom scans was changed from 60bpm to 100bpm in the middle of the scan.

Results and discussion:

Phantom: The SI of water phantoms remained constant without and with fat suppression, while fat suppression led to fat SI close to background (Fig. 2). Under the presence of heart rate variations the static timing led to an SI increase of normal myocardium, fat, and background. Heart rate adaptive timing achieved the suppression of normal myocardium and fat equally well with fixed and variable heart rate. SI of enhancement decreased with variable heart rate because the inversion time decreased with increased heart rate.

In vivo: With adaptive TI selection the technique led to nulling of signal from healthy myocardium and from fat (Fig. 3). Enhancement in (Fig. 3(c,d)) is recognized as pericardial effusion with fat suppression.

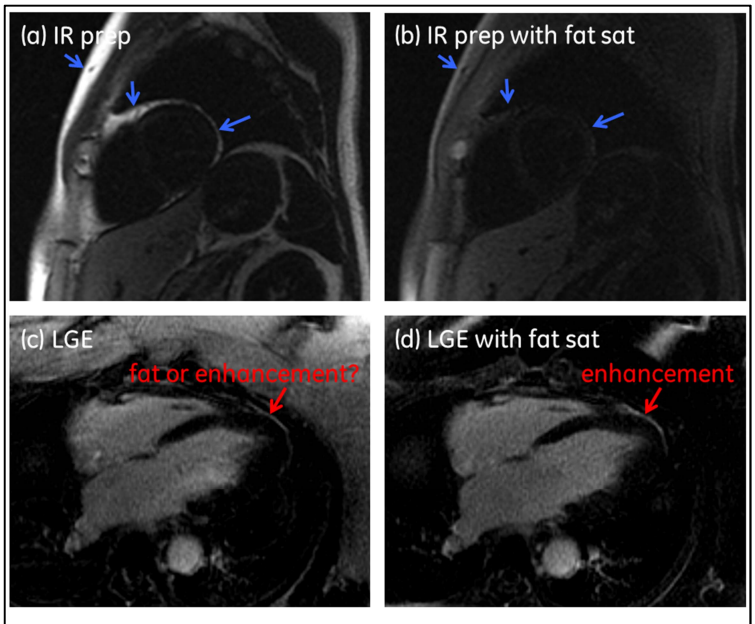

Fig. 3: *IR prepared images from the heart of a (a, b) healthy volunteer and (c,d) patient with contrast. The new technique led to suppression of normal myocardium and fat signal (blue arrows), thus better visualization of enhancement (d, red arrow). Corresponding images have same window level.*

Conclusions: The technique presented here was proven to robustly suppress fat in more than 30 clinical cases and was demonstrated to be robust against heart rate variations. One benefit of fat-suppressed LGE imaging is the ability to remove pericardial fat signal and better visualize pathology in patients with pericardial enhancement.

References: 1. TK Foo et al., JMRI, 2007, p. 927; 2. WG Rehwald et al., ISMRM 2011, 2622; 3. TL Hwang et al., JMR, 1999, p. 173