Non-selective double inversion recovery pre-pulse for flow-independent black blood myocardial viability imaging

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Introduction & Purpose: MRI late gadolinium enhancement (LGE) using the inversion-recovery (IR) sequence is the current gold standard for the assessment of myocardial viability. Although it achieves high contrast between infarct and normal myocardium, there is often poor infarct-to-blood contrast. Flow-dependent and diffusion-prepared black-blood LGE techniques have previously been described.[1,2] The use of multiple inversion delays to achieve signal suppression has been previously studied, either to achieve simultaneous nulling of the signals of two species with different T_1 times[3, 4] or for total suppression from tissues with different T1 times.[5, 6] Recently this principle was extended to T_1-independent flow suppression in carotid plaque imaging[7]. We sought to improve infarct-to-blood contrast in LGE myocardial viability imaging using a novel non-selective double inversion technique that provides flow-independent signal suppression over a wide user-defined T_1-range. This approach allows simultaneous nulling of signal from both the blood and normal myocardium while maintaining high signal in the infarcted region.

Methods: ***NS-DIR pre-pulse:*** A non-selective double-inversion recovery (NS-DIR) sequence with two time delays, TI_1 and TI_2, was implemented on a 3T Philips Achieva MR-scanner (Philips Healthcare, Best, NL). TI_1 and TI_2 were optimized in MATLAB simulations by minimizing $M_Z^{NS\text{-}DIR}$ over several user-defined T_1-ranges for a given heart rate.
Phantom experiments: A T_1-phantom containing 11 T_1-samples (T_1-range=120ms-1730ms) was imaged with the NS-DIR pre-pulse. Images were acquired for the TI_1 and TI_2 times optimised to null signal for T_1-ranges between 200-1400ms, 300-1400ms and 400-1400ms for simulated heart-rates between 45 and 105bpm. For each of the images, the signal-to-noise ratio (SNR) was calculated for each sample.
Patient Studies: Six patients with and one without myocardial infarction on conventional LGE images were imaged ~15-60 minutes after injection of a double dose of Gadolinium-DTPA (Magnevist, Bayer-Schering) using a 32-channel coil on a 3T Philips Achieva MR Scanner. Firstly a breath-hold 2D IR segmented gradient-echo (TFE) sequence was acquired in standard views. Imaging parameters included: spatial-resolution=1.54x1.75x8mm, TR/TE=3.8ms/2ms, FA=25°, TFE factor=25 and TI chosen using a Look-Locker sequence. Subsequently, identical planes were repeated with the IR replaced by the NS-DIR pre-pulse with imaging parameters maintained. TI_1 and TI_2 were set to suppress the T1-range (the minimum cut-off was set between 200 and 400ms and the maximum always set at 1400ms according to the patient's heart-rate.) Imaging was performed over one heartbeat except in one patient with a heart-rate of 90bpm who was imaged over two heartbeats. To examine the effect of contrast wash out on the blood signal, in two patients, IR imaging was repeated after the NS-DIR scan. CNR (infarct/myocardium) and CNR (infarct/blood) were calculated in all the IR and NS-DIR images.

Results: ***Simulations & Phantom experiments:*** $M_Z^{NS\text{-}DIR}$ simulations (Fig.1a) indicate excellent signal suppression over the desired T_1-range with corresponding phantom studies in good agreement (Fig.1b). At high heart-rates, low T1 species are suppressed to a greater extent, which may be compensated for by a higher T1 cut-off value or by imaging over two heart-beats. ***Patient Studies:*** All NS-DIR images demonstrated excellent blood signal suppression and allowed visualisation of the infarct in all but one patient. In this case, failure of infarct visualization was most likely attributed to imaging every heart-beat at a high heart rate. Due to the improved blood suppression using the NS-DIR pre-pulse, scar was consistently better delineated in the NS-DIR compared to IR images (Fig. 2-3). The average infarct/myocardium CNR was 10.0±1.1 for the IR sequence and decreased to 6.5±1.8 for the NS-DIR sequence while the average infarct/blood CNR increased from 1.8±1.8 to 5.3±1.4 with the NS-DIR technique when compared to the IR sequence. No statistically significant difference in CNR was found for the different T1- suppression ranges, however, imaging over 2 heart-beats at high heart-rates demonstrated improved infarct visualisation.

Conclusions: We have developed a new flow-independent LGE sequence for improved contrast and infarct visualization. Simulations and phantom studies demonstrate excellent tissue suppression over a wide T_1-range. Preliminary patient data show an improvement in infarct/blood CNR. This technique facilitates detection of sub-endocardial defects and potentially more accurate quantification of infarct size and transmurality.

References: **(1)** Salerno, M. et al. Proc. ISMRM,15(2007):p.3582. **(2)** Salerno, M. et al. JCMR 11(2009):p.8. **(3)** Redpath, TW. Et al. BJR 67(1994):p.1258-63. **(4)** Mai, VM et al. MRM 41(5)(1999):p.866-70 **(5)** Dixon, WT et al. MRM, 18(2)(1991)p.257-68. **(6)** Mani, S. et al. MRM, 37(6):(1997).p.898-905. **(7)** Yarnykh, V.L. et al. MRM. 48(5): (2002):p.899-905.

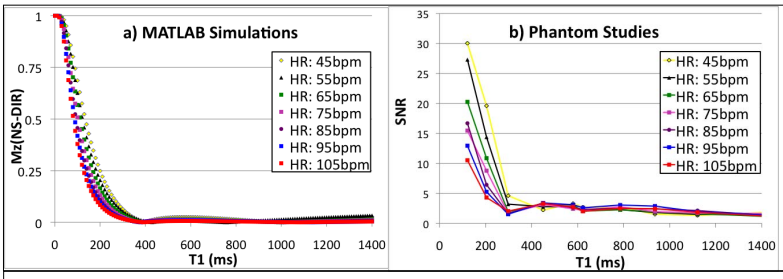

Figure 1:
a) Simulated $M_Z^{NS\text{-}DIR}$ curves for TI_1 and TI_2 values optimized to minimize $M_Z^{NS\text{-}DIR}$ for a T1 range between 200 and 1400ms for different heart rates.
b) The corresponding SNR values measured in phantom images using the same TI_1 and TI_2 settings are in good agreement with the simulations.

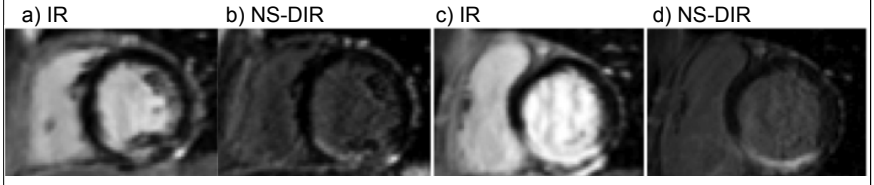

Figure 2: Patient with inferior wall infarct (HR= 50bpm) demonstrating suboptimal infarct to blood differentiation on IR TFE images (a and c) while improved infarct to blood delineation can be observed on NS-DIR TFE images (b and d).

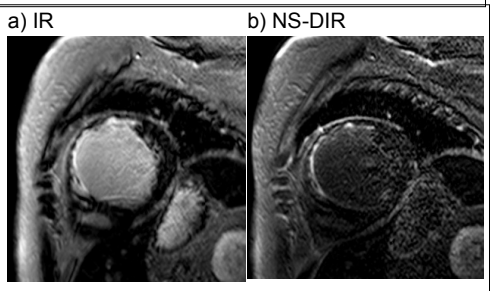

Figure 3: Patient with anterior, anterolateral & septal wall scar (HR= 60bpm) shows poor CNR(infarct/blood) on IR-TFE image (a) while NS-DIR-TFE image (b) has excellent infarct delineation.