Double Inversion Recovery First-Pass Myocardial Perfusion Imaging at 3 Tesla

K. Sung[1], Y-C. Kim[1], H. H. Hu[1], and K. S. Nayak[1]
[1]Electrical Engineering, University of Southern California, Los Angeles, CA, United States

Introduction: First-pass myocardial perfusion imaging (MPI) has become an established MR technique for assessing myocardial ischemia. Saturation-recovery is the preparation typically used to produce T1 contrast [1,2]. Inversion recovery (IR) provides stronger T1 contrast, but is very sensitive to heart rate variation. Achieving multi-slice IR MPI with acquisition on every heartbeat is difficult [3]. In this work, we propose a new double-IR MPI method that attempts to maximize signal contrast between enhanced (short-T1) and non-enhanced (long-T1) by nulling the short-T1 signals. We hypothesize that the double-IR technique can improve contrast compared to saturation-recovery techniques, and facilitate improved visual conspicuity of perfusion defects.

Methods: Figure 1 illustrates the proposed double-IR pulse sequence. Longitudinal magnetization of short-T1 spins (M_{ZS}) recover quickly after the first inversion pulse, while that of long-T1 spins (M_{ZL}) recover more slowly. The second inversion pulse is applied shortly after M_{ZS} passes through zero and becomes positive. As a consequence, the partially-recovered M_{ZS} is re-inverted into the negative Z-axis while the slower-recovering M_{ZL} is returned to the positive Z-axis. The second inversion pulse effectively assists T1-recovery of M_{ZL}. Snapshot imaging is performed as M_{ZS} passes through zero for the second time, and captures signal contrast between M_{ZS} and M_{ZL}. By choosing a proper flip angle in the snapshot acquisition, contrast between steady-state M_{ZS} and M_{ZL} can be maximized. A unique feature of the proposed technique in comparison to conventional SR and single-IR is *inverted* signal contrast between healthy (long-T1) and ischemic (short-T1) myocardium (i.e. non-contrast-enhanced myocardium is *brighter* than contrast-enhanced myocardium). The two inversion pulses (10 ms) are non-slice-selective and adiabatic. Snapshot imaging consists of a 3.6 ms spectral-spatial RF excitation and a partial k-space EPI that minimizes TE (and hence T2* effects).

The inversion times (TI_1 and TI_2), the imaging flip angle α, and the subject's heart rate together determine the steady-state signal and the level of T1 contrast of the acquisition. TI_1, TI_2, and α for a given heart rate are optimized to produce maximum signal difference between long-T1 (1220 ms) and short-T1 (100 and 200 ms) species. Two separate preliminary data sets were obtained on healthy volunteers by selecting inversion times that allowed nulling of T1 = 100 ms (expected T1 of maximally-enhanced blood) and T1 = 200 ms (expected T1 of maximally-enhanced myocardium). The inversion times were TI_1 = 80 ms, TI_2 = 10 ms, and α = 55° for T1 = 100 ms and TI_1 = 144 ms, TI_2 = 10 ms, and α = 55° for T1 = 200 ms. For each study, 0.1 mmol/kg of Gd-DTPA was injected at 3 ml/s. Experiments were performed on a GE Signa EXCITE HD 3.0T system. Other imaging parameters were: TE/TR = 4.5/18.5 ms, FOV = 25×25 cm^2, 3.6×3.6 mm^2 resolution, 8 mm slice thickness, homodyne reconstruction.

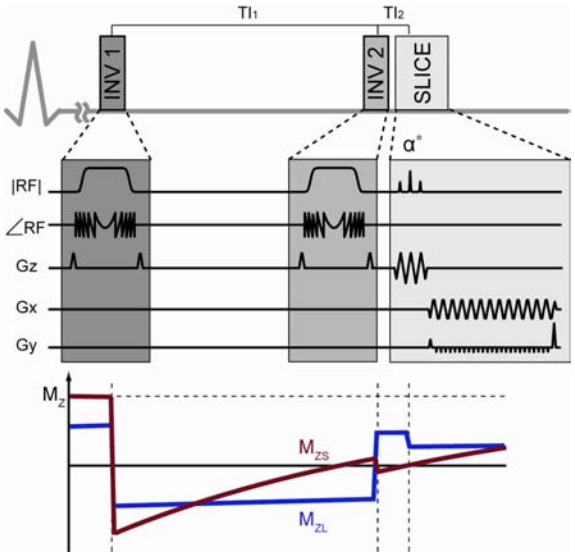

Figure 1: Double-IR MPI pulse sequence and steady-state signal. **INV1 and INV2**: 10 ms non-selective adiabatic inversions followed by gradient dephasers. **SLICE**: 3.6 ms spectral-spatial excitation and partial k-space EPI acquisition. M_{ZS} and M_{ZL} correspond to the steady-state longitudinal magnetization of T1 = 100 ms and 1220 ms respectively.

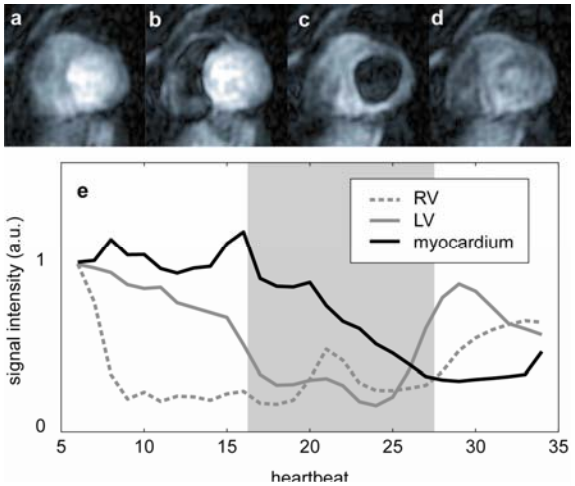

Figure 2: First-pass Double-IR MPI images: (a) Pre-contrast, and as contrast enters the (b) RV, (c) LV, (d) myocardium; and (e) Time-intensity curves from the RV, LV and septal myocardium. Myocardial signal reduction during the first-pass is highlighted in gray.

Results: Figure 2 contains images from first-pass double-IR MPI and corresponding normalized time-intensity curves from the RV, LV, and septal myocardium in one health volunteer (null T1 = 100 ms). Signal decay of healthy (short T1) myocardium is clearly observed during the first-pass of the contrast agent (gray box). Note that the LV blood pool is near-completely suppressed at the point of highest contrast agent concentration.

Discussion: Preliminary single-slice results suggest the feasibility of double-IR MPI. The generation of inverted contrast where brighter signal intensity is indicative of underperfused myocardium may be visually beneficial in the clinical setting. The double-IR sequence can be extended to multi-slice applications by 1) using slice-selective inversion pulses and concatenating inversion pulses such that the second inversion of a current slice is also the first inversion of the next slice, or 2) using a series of slice-selective first inversions and one nonselective second inversion to prepare all the slices. There is also a trade-off between the selection of the T1 value to be nulled, imaging parameters and speed, and the resultant degree of signal difference between non-enhanced and enhanced myocardium. Another concern is the possibility of partial-volume artifacts at the myocardium-blood pool boundary.

References: [1] Wang Y, et. al. MRM, 54, p1123-1129, 2005. [2] Fenchel M, et. al. JMRI, 19, p555-563, 2004. [3] Atkinson DJ, et al. Radiology, 174 (3):757-762, 1990.