Improved Contrast in Myocardial Delayed Enhancement using Dual Inversion Time Subtraction

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Introduction

Visualization of myocardial delayed enhancement necessitates the selection of an optimum inversion time (TI) to suppress the signal from normal myocardium to better visualize signal from hyper-enhancing infarcted tissue [1-4]. Different techniques have been proposed to improve the visualization of myocardial infarction following the administration of a cumulative 0.2 mmol/kg of Gd contrast media. These include the use of a TI optimization sequence where several acquisitions, each with a different TI time, are made. The user then selects the TI time that has the optimal suppression of the normal myocardial signal. In addition, phase-sensitive reconstruction of the inversion-recovery prepared (PSIR) images [5] have also been proposed. This method avoids the contrast inversion that is a feature of magnitude reconstructed inversion-recovery prepared images. The latter technique requires a less precise selection of the TI time if that time is less than the null point for normal myocardial tissue. However, in both approaches, there is sometimes insufficient contrast between the infarct and the ventricular blood pool, making discrimination of the endocardial borders of the infarct difficult. A technique utilizing two different TI times is proposed that increases the contrast between the infarcted tissue and ventricular blood, over that obtained with either magnitude or PSIR images.

Materials and Methods

Representative signal intensity (SI) curves of infarcted tissue (T1 = 75 ms), blood (T1 = 135 ms) and normal myocardium (T1 = 290 ms) are shown in Fig. 1. Contrast between the infarcted tissue and normal myocardium are equivalent with either PSIR or magnitude IR methods if the TI selected is greater than that of the null point of normal myocardial tissue ($TI_{null} = 0.69*290 = 200$ ms). If the TI selected is less than that of the null point, PSIR exhibits greater contrast than that of magnitude IR.

For TI times +/- 75 ms from the true null point, contrast between the infarcted tissue and the blood pool is small for both PSIR or magnitude IR techniques. The contrast between infarcted tissue and the blood pool is much higher at shorter TI times. If we recognize that at a very short TI time (≈50 ms), the signal intensity of the infarct is small or close to zero, with a larger signal intensity for blood and a much larger signal intensity for normal myocardium, we see that the image acquired at this TI time can be used to reduce the overall signal from blood and much greatly reduce any residual normal myocardial signal. If TI = a represents the short TI time, $SI_{infarct}(a) < SI_{blood}(a) << SI_{myo}(a)$. At the longer time, TI = b, $SI_{infarct}(b) > SI_{blood}(b) >> SI_{myo}(b)$, $SI_{myo}(b) \rightarrow 0$. By subtracting the magnitude signal intensities at the two different TI times ($\Delta SI = | SI(b)| - |SI(a)|$), the resulting infarct SI is reduced minimally by the SI at the short TI time. The SI of blood is reduced to a greater extent due to the larger SI at TI=a, while the SI of the normal myocardium is substantially reduced due to the large SI at TI=a and small SI at TI=b.

A proof-of-concept was demonstrated in 3 anesthestized dogs that had induced myocardial infarctions. Standard 2D inversion-recovery myocardial delayed enhancement (2D MDE) in addition to 3D MDE sequences were used. An initial TI of 50 ms was used for the short TI time and TI of 250-270 ms used for the long TI acquisition. A TI optimization was also performed to acquire images at an optimal TI time for comparison purposes. In all cases, a cumulative 0.2 mmol/kg Gd contrast dose was given. The signal-difference-to-noise ratios (SDNR) for the subtracted as well as the TI optimized images were calculated.

Results

Four different regions of myocardial infarction were selected. Using the subtraction technique, the SDNR between the infarct and blood improved by 30% ($p < 0.02$). There was no statistical difference in infarct-myocardial SDNR ($p<0.65$) between the TI optimized and subtracted images. Thus, the contrast between the infarcted zone and the ventricular blood improved without degrading the infarct-normal myocardial contrast using the subtraction technique. Fig. 2 shows demonstrates the improved conspicuity of the endocardial borders of the antero-septal infarct compared to the optimized MDE images. The increased noise from the subtraction is compensated by the improved dynamic range of the subtracted images.

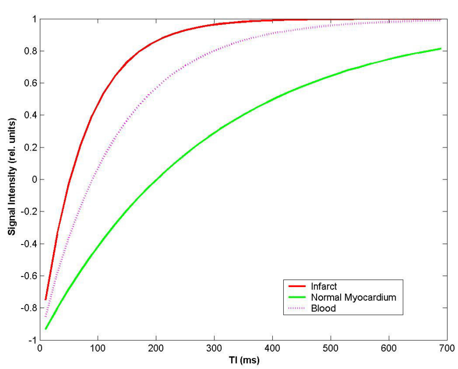

Fig. 1: Signal intensity curves for infarcted tissue, blood and normal myocardium as a function of TI in an inversion-recovery experiment. Note that infarct-blood contrast is unaffected by PSIR or magnitude IR methods.

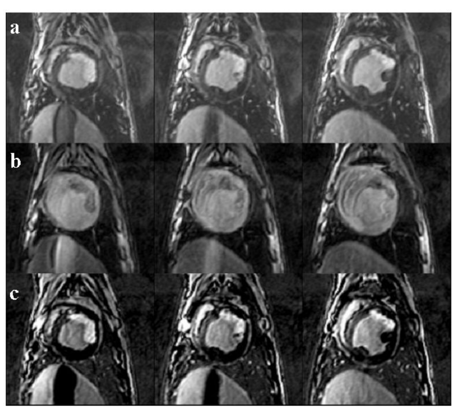

Fig. 2: (a) optimized 3D MDE images at TI=200 ms; (b) 3D MDE images at TI = 50 ms showing the reduced infarct signal at this inversion time, and (c) subtracted images (TI=270 ms – TI=50 ms). Note that the infarct-blood contrast has improved sufficiently to better visualize the endocardial borders of the infarcted region.

Note also that despite the fact that TI=270 ms images were chosen, infarct-myocardium contrast was equivalent to that of the optimized TI = 200 ms images

Conclusions:

We have demonstrated a new technique that improves the conspicuity of the endocardial-ventricular blood pool margins of infarcted tissue. Moreover, the technique is relatively TI insensitive as infarct-myocardial contrast is maintained despite the long and short TI times used.

References

1. Lima JA, et al. Circulation 1995; 92: 1117-25.
2. Wu KC, et al. J Am Coll Cardiol 1998; 32: 1756-64.
3. Wu KC, et al. Circulation 1998; 97: 765-72.
4. Kim RJ, et al. Circulation 1999; 100: 1992-2002.
5. Kellman P, et al. Magn Reson Med 2002; 47: 372–83.