# Multi-Slice Phase Sensitive Delayed Hyperenhancement MRI of Myocardial Infarction

Andrew E. Arai, Peter Kellman, Anthony H. Aletras

Laboratory of Cardiac Energetics, National Heart Lung and Blood Institute, Bethesda Maryland 20892 USA

## INTRODUCTION

Improved methods of imaging delayed Gd-DTPA hyperenhancement [Simonetti 2000] have established MRI as the highest resolution assessment of myocardial viability [Kim2000]. Cardiac motion and a desire to null normal myocardium limit the acquisition window during each RR interval. Attempts to increase cardiac coverage such as 3-D acquisitions have thus far required significant compromises in resolution to stay within these constraints.

Phase sensitive reconstruction of IR-prepared images (PS-IR) achieves excellent contrast between the infarct and normal myocardium over a broad range of inversion times [Kellman, in press]. We hypothesized that PS-IR would allow us to obtain multiple slices per heart beat with no compromise in image resolution or increase in motion artifact.

## METHODS

Images were acquired from 11 patients with IR gradient recalled echo imaging on a GE Signa CV/i clinical scanner. Imaging parameters were as follows: TE 3.4ms, TR 7.8ms, RF flip angle 20o (5o for reference image acquired on alternate heartbeats), bandwidth 32kHz, 16 ky lines per RR per slice, FOV 360x270mm, matrix 256x96, slice 8mm, number of averages 1. The data acquisition time per RR per slice was 16x7.8=125ms. Data for 4 slices per RR were collected resulting in 500 ms long acquisition windows. The TI for the first slice was between 125-200ms, and 125ms additional per slice. As described previously [Kellman, 2002], IR and phase reference ky lines were acquired every other heartbeat for a total breath-hold time of 12 heartbeats. Interleaving the slices (odd slices during the first breath-hold, even during the second) resulted in reduced cross talk. Conventional single slice per breath-hold PS-IR imaging was also performed for comparison purposes.

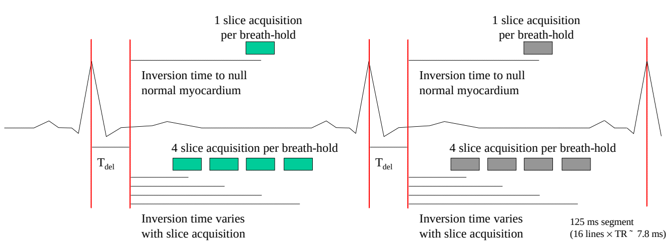



**Figure 1. Comparison of single slice and multislice acquisition timing.** Conventional inversion recovery (IR) acquires one segment of k-space in diastole every other heartbeat. With phase sensitive single slice IR, a T1 weighted segment is acquired on the first heartbeat and a non-T1 weighted reference image is acquired on the second heartbeat. The inversion time is adjusted to null the normal myocardium on the magnitude reconstructed image.

For the multislice acquisitions, T1 weighted segments (green boxes) from different slices are taken at different phases of the cardiac cycle with corresponding reference images (gray boxes) acquired on the second heartbeat. With this approach, one or none of the segments will be acquired at the optimal inversion time to null normal myocardium. However, since phase sensitive reconstruction maintains the polarity of $M_z$, excellent contrast is achieved for slices obtained over a much wider range than achievable with magnitude reconstruction.

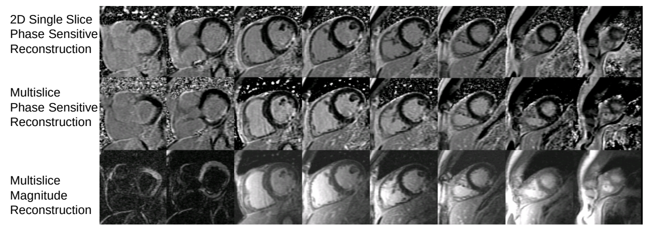
## RESULTS

**Figure 2. Comparison of 2D and Multi-slice Infarct Imaging.**

**Top row:** Conventional 2D acquisitions; 8 slice locations acquired in 8 separate breathholds using phase sensitive reconstruction.

**Middle row:** Multi-slice phase sensitive reconstruction; the same 8 slice locations acquired in 2 breathholds.

**Bottom row:** Magnitude reconstruction of the acquired multi-slice data shows the TI was quite far from optimal in all but slices 5&6.




On average, multi-slice PS-IR increased the number of lines of k-space acquired by a factor of 4 while maintaining the same breathhold duration (12 heartbeats). Compared with conventional 2D single slice methods, multi-slice PS-IR data was of comparable diagnostic quality in all 11 patients. Figure 1 shows a comparison of a 2D single slice per breath-hold, the new multi-slice PS-IR method, and reconstruction of the same multi-slice data from a patient with an inferior infarct. This example shows similar definition of the infarct for the 8 separate breathholds of the 2D single slice method (top row) and the multi-slice method (middle row), both with phase sensitive reconstruction. The multislice magnitude data (bottom row) shows only 2 of the multi-slice locations were close to the optimal TI.

**Figure 3. $M_z$ versus Inversion Time (top panel) and Infarct-to-Normal Myocardium contrast (bottom panel).** With phase sensitive reconstruction, contrast remains within ~20% of the optimal TI over a wide range of inversion times. With magnitude reconstruction, contrast is reduced at inversion times between ~175 and 275 ms.

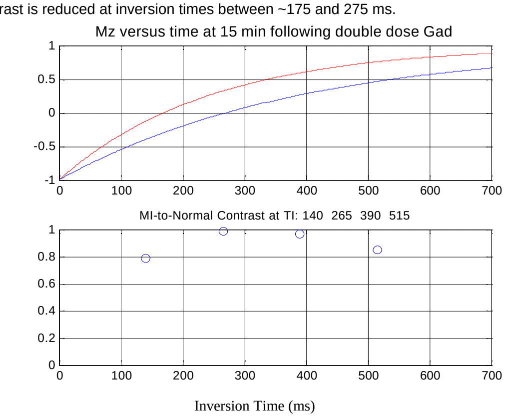



**Figure 4. Comparison of magnitude reconstruction and phase sensitive reconstruction methods over a wide range of inversion times.** In this example, the magnitude images at an inversion time of *** ms demonstrate appropriate nulling of the normal myocardium. The apparent infarct size decreases at shorter inversion times on images created with magnitude reconstruction. Exactly the same data, when processed with phase sensitive reconstruction, results in constant infarct size and appearance over a wide range of inversion times.

## DISCUSSION

Unlike magnitude reconstruction methods, phase sensitive reconstruction allowed imaging across a broad range of inversion times while maintaining good contrast between the MI and normal myocardium. By using multiple segmented 2-D slices, the number of lines of k-space acquired per heartbeat was increased by a factor of 4 within the cardiac cycle without a change in motion blurring or breathhold time. This reduced the number of breath-holds needed to image the heart from 8 to 2 with no compromise in image resolution.

Using average tissue parameters at 20 min post contrast agent, the estimates of CNR (MI-to-normal, myocardium) for single slice and multi-slice were calculated. The optimal CNR is obtained at TI=325 ms, and multi-slice PS-IR images achieve 85, 99, 96, and 85 percent of the optimum for images acquired at TI=175, 300, 425, and 550 ms, respectively. PS-IR methods can be combined with additional acceleration methods such as SENSE or partial-NEX to further reduce breath-hold time.

## REFERENCES

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