Cardiac Tagging at 3 Tesla

N. Pack[1,2], E. V.R. DiBella[1,2]

[1]Department of Bioengineering, University of Utah, SLC, Utah, United States, [2]UCAIR, Department of Radiology, University of Utah, SLC, Utah, United States

Introduction: Magnetic Resonance (MR) tagging is a valuable tool for the qualitative and quantitative assessment of cardiac motion and function. In order to accurately quantitate cardiac motion and strain, processing tools such as Harmonic Phase (HARP) MRI require that there is a good tag-to-tissue contrast ratio and that tags persist as long as possible. While efforts have been made in the last decade [1][2][3] to improve tagging parameters and pulse sequences at 1.5 Tesla, little has been done to optimize tagging parameters at 3 Tesla. In this work, we evaluate the signal difference to noise ratio (SDNR) for tagged phantom images and analyze human tagged cardiac image data using the HARP method.

Methods: (a) *Phantom images*: A Siemens 3 Tesla Trio was used to acquire a series of tagged images of a uniform cylindrical phantom. The T1 of the phantom was approximately 950ms, which is near the published T1 of 1115ms for myocardial tissue at 3 Tesla [4]. Tagged images were generated using a gradient echo pulse sequence (TR/TE 7.0/3.8) with a different flip angle for each series. The flip angle varied from 10˚ to 30˚ and a constant tag spacing of 6mm was used in the imaging sequence. For each sequence of tagged phantom images, untagged and tagged ROIs were selected and an average signal difference (SD) was computed. The SD was divided by the background noise to compute an average signal difference noise ratio (SDNR).

(b) *Patient images and HARP analysis*: Tagged cardiac MR images were obtained from healthy volunteers at rest. A gradient echo sequence was used on a Siemens 3 Tesla Trio to generate tags at end-diastole and acquire 18 phases of the cardiac cycle for one short-axis slice of the heart. This was repeated for vertically and horizontally oriented tags with a tag spacing of 8mm. The tagged datasets were analyzed using a HARP algorithm implemented in Matlab, which parallels the technique introduced by Osman et al [5].

Results and Discussion: Figure 1 depicts the SDNR curves for four flip angles used in the phantom tagging sequence. From these curves, it is noted that the tagged images acquired at 10˚ resulted in the highest initial SDNR and in the longest tag persistence.
For the phantom imaging, the predicted Ernst angle was determined to be 6.9˚. The lowest achievable flip angle—due to system constraints—was 10˚. This is only slightly larger than the theoretical prediction and it demonstrates that, at 3 Tesla, a flip angle lower than the commonly used 15˚ flip angle used at 1.5 Tesla is a more optimal choice.
Figures 2a and 2b show a series of vertically and horizontally tagged images during five phases of the cardiac cycle, beginning at end-diastole. Figure 2c shows the 2D Eulerian strain maps computed from HARP that correspond to the apparent planar motion of the vertical and horizontal tags. The light orange colored regions indicate near-zero strain, while the darker (reddish) regions indicate tissue compression and the lighter (yellow-green) regions indicate tissue stretching. In later time frames, regions of increased stretch and compression are progressively more visible, reaching a maximal strain of nearly 30%. This reflects the expected trend reported in previous work at a magnetic field strength of 1.5 Tesla [2].

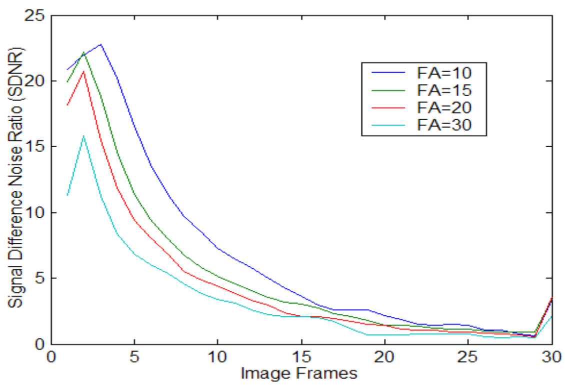

Figure 1: SDNR curves for phantom tagged images with variable flip angles (FA)

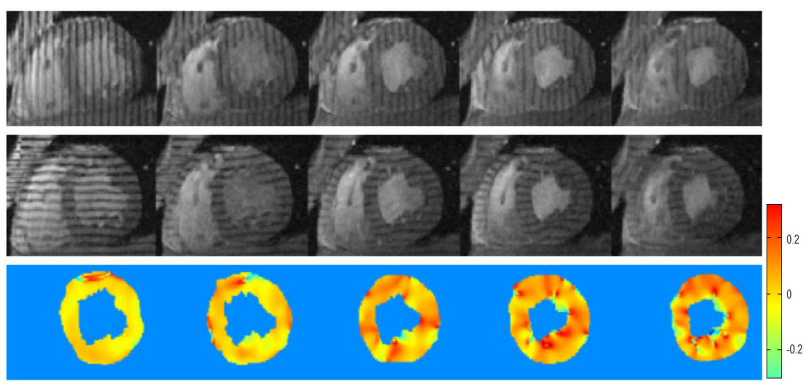

Figure 2: (a) Vertically and (b) horizontally tagged cardiac images of the left ventricle (LV) and (c) the corresponding 2D Eulerian strain maps computed using HARP

Conclusion: At a field strength of 3 Tesla, a reduced flip angle from 1.5 Tesla produces a higher SDNR ratio. Furthermore, when vertical and horizontal tags were generated for the cardiac tagging study, tags were clearly visible throughout the entire systolic phase and into the diastolic phase of the cardiac cycle. From the myocardial tagged images, the strain maps computed using the HARP algorithm clearly depict a progressive deformation of the LV myocardium throughout the systolic phase of the cardiac cycle. The maximal strain calculated using the HARP method at 3 Tesla closely parallels the maximal strain reported by the HARP method at 1.5 Tesla. Additional patient and phantom studies to optimize tagging methods at 3 Tesla are in progress.

References:

[1] Markl M, Reeder S, Chan F, Alley M, Herfkens R, Pelc N. SSFP MR Imaging: Improved Myocardial Tag Persistence and SNR for Analysis of Myocardial Motion. Radiology 2004; 230:852-861.
[2] Atalar E, McVeigh ER. Optimization of Tag Thickness for Measuring position with MRI. IEEE Trans Med Imag 1994; 13:152-160.
[3] Fischer SE, Mckinnon GC, Maier SE, Boesiger P. Improved Myocardial Tagging Contrast. Mag Reson Med 1993; 30:191-200.
[4] Noeske R, Siefert F, Rhein KH, Rinneberg H. Human Cardiac Imaging at 3T Using Phased Array Coils. Magn Reson Med 2000; 44:978-982.
[5] Osman NF, Prince JL. Visualizing myocardial function using HARP MRI. Phys Med Biol 2000; 45:1665-1682.