Comparison of HARP MRI Tagging Analysis and Manual Approach for Quantification of Left Ventricular Strain in Rats after Myocardial Infarction

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Abstract

Harmonic Phase (HARP) analysis of MR tagging was proposed for fast and automated assessment of myocardium kinematics. In this study, its outcome was evluated in a rat model of myocadial infarction with comparsion to maunally based approach. The results indicated that manual and HARP analysis exhibited a good concordance in assessing alterations in myocaridium wall motion despite the fact that the calculated strains were in different state. Manual and HARP analysis yielded similar results for assessment of the strain patterns in both control and infarct rats. Both methods detected significant changes in E2 strain after myoicardial infarction.

Introduction

MR tagging allows comprehensive and noninvasive assessment of myocardial wall motion. Measuring the deformation of tag lines allows quantitative evaluation of regional wall motion. Over the last decade, numerous studies using this technique have led to many insightful findings. However, manual or semi-automated analytical approaches that require substantial user input and time are unsuitable for large studies or clinical use. Recently, harmonic phase (HARP) analysis[1] has been proposed for fast and fully automated assessment of myocardium kinematics. With single shot HARP the strain field can be computed rapidly and nearly automatically at single time point. While HARP analysis possesses the potential for rapid quantification of tagged images, its outcome remains to be validated. The suitability of the technique for experimental use in small animals is unknown. Accordingly, we compared the results of manually based algorithms and HARP analysis in a rat model of myocardial infarction to establish the extent of concordance of the techniques.

Methods

MR imaging: MRI tagging was performed on 20-month old Fischer 344 rats 4 weeks after infarction. Infarction was created by occlusion of the left coronary artery descending branch (n=5). Five age-matched, sham-operated rats were used as the controls. MR imaging was performed on a Varian 4.7T scanner with a birdcage RF coil. Tagged short-axis images at midventricular level, which was chosen at 50% of the distance between the atrioventricular valve plane and apex, were acquired. The tagging sequence used a SPAMM1331 sequence applied twice immediately after the ECG trigger, yielding a two-dimensional tag grid in imaging plane. The tagging sequence was followed by gradient-echo cine sequence with the following imaging parameters: TR/TE,14.7ms/3ms; field-of-view, 6.5cmx6.5cm; matrix size, 256x256; tagging resolution, 0.9mm; slice thickness 1.5mm.

Manual based algorithm: Epicardial and endocardial borders, and intersecting tag points were traced manually. Strain calculation used the 2D strain tensor analysis and the methods of eigen system solutions to solve for principal strains. The Lagrangian strain tensor (*E*) was used to relate lengths of infinitesimal line segments in the undeformed state to its deformed state in the case of small deformations (see Eq1.), Where ds_0 was the length of the line segment in the undeformed state and *ds* was the length in the deformed state. Principal strain E1 was defined as the maximum elongation strain, which is an index of wall thickening. Principal strain E2 was defined as the maximum compression strain, which is an index of circumferential shortening.

HARP analysis: The first harmonic peak of the spectrum was isolated followed by inverse Fourier transform to generate the HARP image *a(y,t)*. Using the ventricular contours generated by the manual algorithm, the Cauchy strain tensor (ε) was caculated directly from the HARP image without tag line tracing by Eq2[1], where ∇^* is the modified gradient operator, *H=[h1,h2]* are the vectors descrbing the image orientation, *W=[w1,w2]* are tagging vectors.

$$ds^2 - ds_0^2 = 2E_{ij}da_i da_j \quad \text{Eq1.}$$

$$\varepsilon(y,t;e) = \left\| \left[\nabla_y^* a(y,t)\right]^{-1} W^T He \right\| - 1 \quad \text{Eq2.}$$

Results

Shown in Figure 1 are tagged images of an infarct rat heart at 80% systolic cycle. Due to the noise generated by HARP analysis at end systolic cycle, all the data shown were acquired at 80% systolic cycle. In Figure 2, the infarct group demonstrated significant decrease in pricipal strain E2 by both methods (–0.15±0.02 vs -0.18±0.01 for manual analysis, $p<0.05$; –0.15±0.01 vs –0.18±0.02 for HARP analysis, $p<0.05$ each). The calculated E2 values by both methods were alsos similar (p=NS each). A strong correlation with a slope of 1.02 existed between manual and HARP analysis of E2 (R=0.91, Figure 3). For pricipal strain E1 , no significant changes were observed in infarct rats from either method (0.38±0.12 vs 0.36±0.05 for manual analysis; 0.24±0.10 vs 0.24±0.04 for HARP analysis, p=NS each). However, the results from HARP analysis was significantly smaller than those from maunal analysis ($p<0.01$). The correlation between manual and HARP analysis was also less strong with a slope of 1.82 (R=0.79). This discrepency may be accounted for by the difference between Lagrangian strain and Cauchy strain. While Lagrangian strain calculated from manual analysis is based on nondeformed state, Cauchy strain generated from HARP analysis is based on deformed state. When the deformation is small, as in the case of circumferential shortening, the two strains are comparable. However, since the magnitude of E1 is much bigger than E2, discrepency tends to occur.

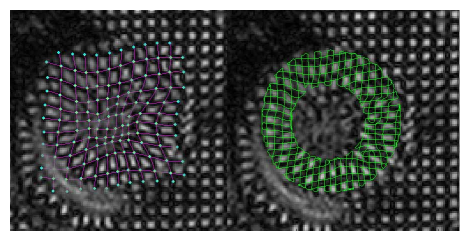

Figure 1. Tagged short-axis images of an infarct rat heart. Left: Manually traced tag lines. Right: Sythetic tag lines generated by HARP with phases equal to π/2.

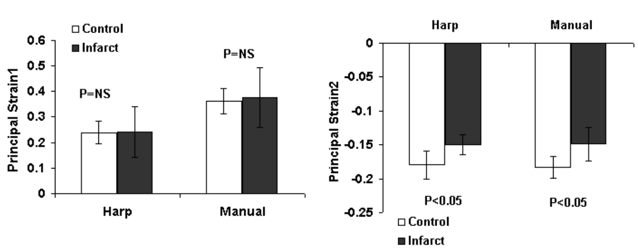

Figure 2. Principal strains of infarct and control rats

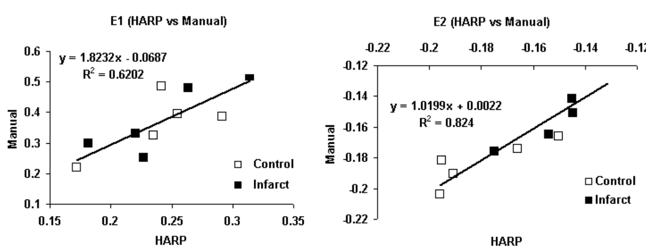

Figure 3. Correlations of manual and HARP analysis

Conclusion

Although manual and HARP analysis calculate strains in different state, they exhibited a good concordance for assessing myocaridium wall motion. Manual and HARP analysis yielded similar results for assessment of the strain patterns in both control and infarct rats. Both methods can differenitate infarct from control in terms of principal strain E2. Since HARP analyis is a faster and fully automated approach, it should facilitate the studies of cardiac wall motion.

Reference

1. Osman NF, McVeigh ER, Prince JL, Imaging Heart Motion Using Harmonic Phase MRI, IEEE Trans. on Med. Img. 19(3):186-202, 2002