CINE CARDIAC VIABILITY IMAGING BY IMAGE FUSION OF MRI TAGGING AND DELAYED HYPER-ENHANCEMENT IMAGES

Azza S. Hassanein[1], Ayman M. Khalifa[1], Brian P. Shapiro[2], and El-Sayed H. Ibrahim[2]
[1]*Helwan University, Cairo, Egypt,* [2]*Mayo Clinic, Jacksonville, Florida, United States*

INTRODUCTION: Delayed-hyperenhancement (DHE) MRI is usually conducted during a single breath-hold acquisition to obtain a viability image at a single heartphase that shows bright myocardium and dark infarction [1]. Nevertheless, obtaining cine DHE images would allow for evaluating both viability and wall motion information from a single set of images without misregistration problems, which could be useful for estimating myocardial contractility reserve (during stress imaging) and for treatment prognosis (e.g. patient selection for revascularization surgery). However, for obtaining cine viability images, the DHE sequence has to be repeatedly played with different trigger delays, which increases scan time and adds the possibility of variable tissue enhancement between different heartphases. In this study, we propose a new technique for generating cine viability images while alleviating these limitations. The technique is based on measuring the motion field of the myocardium from the tagged images, which is used to generate new DHE images throughout the cardiac cycle.

METHODS: In this work, the optical flow technique [2,3] is applied to cardiac MRI tagged images to estimate the motion field of the myocardium from the deformation of the tagging pattern between consecutive heartphases. Specifically, a set of optical flow constraint equations ($I_x V_x + I_y V_y = -I_t$, where V_x and V_y are the *x*- and *y*-components of the flow field of image $I(x, y, t)$, and I_x, I_y and I_t are the image derivatives with respect to *x*, *y*, and *t*, respectively) is solved for the pixels inside a small window using the least squares method. The extracted motion field is used to generate DHE images throughout the cardiac cycle starting from the acquired (known) DHE image (Figure 1). Cubic B-spline interpolation is used to generate a dense displacement field from the estimated positions [4].

The accuracy of the proposed technique was evaluated for generating deformed images on a synthetic dataset of 27 consecutive short-axis (SAX) time frames showing the left ventricle as an annulus that undergoes cyclic radial contraction. Tag fading due to magnetization relaxation was taken into consideration in the simulation. The estimated end-systolic image was compared to the ground truth actual image using the Jaccard and Dice indices [5]. In addition to numerical simulation, datasets of SAX tagging, DHE, and cine images were acquired from a patient with myocardial infarction (MI) on a 3.0 Tesla MRI scanner. The images were processed in Matlab, where the infarcted regions were identified in the DHE images using the full-width at half-maximum method, from which MI transmurality was measured at different segments of the heart. Circumferential strain was measured from the tagged images using the harmonic phase (HARP) technique [6] and radial thickening was measured from both cine and DHE images.

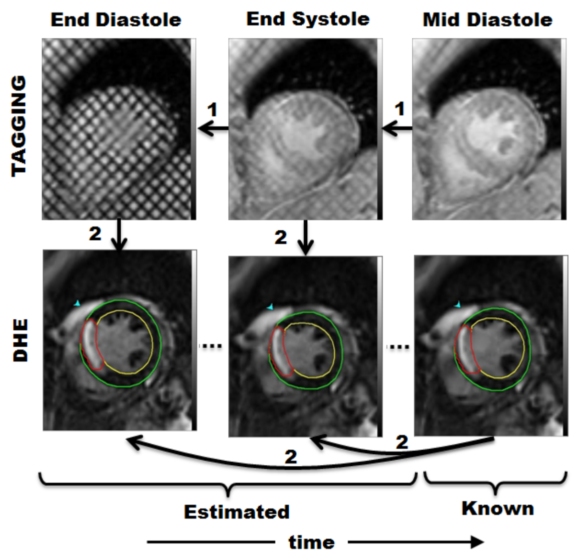

Figure 1. Processing steps and results. All tagged images (top) and one DHE image (bottom right) are acquired in the scan. Starting from the tagged image corresponding to the known DHE image (top right), optical flow is used to extract the motion field at all timeframes (step#1). Then, the measured motion field is used to estimate the missing DHE images (step#2).

RESULTS: In the simulation analysis of the synthetic data, the Jaccard and Dice indices were 0.9114 and 0.9536, respectively. Figure 1 shows a patient's tagged images and the corresponding generated DHE images at different heartphases, where the DHE images show change in the MI shape and myocardial thickening during the cardiac cycle. Figure 2 shows MI transmurality and circumferential strain at different segments in a mid-ventricular SAX slice. Peak MI transmurality (circumferential strain) was 91% (0%) and 0% (-14%) in the septal infarcted and lateral normal regions, respectively. Myocardial thickening, calculated from the DHE images, showed good correlation with the results from the gold-standard cine images (r=0.72). Further, MI transmurality showed good correlation with strain (r=-0.81). It should be noted that strain is represented in negative values; i.e., more negative means better contractility.

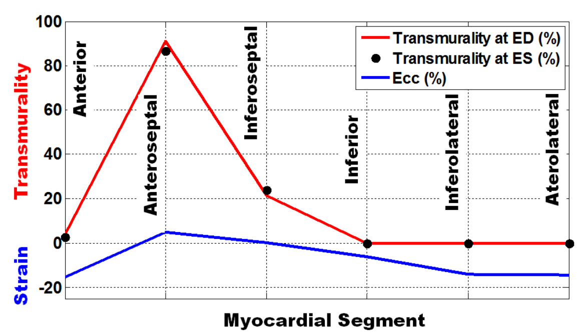

Figure 2. Infarction transmurality and Strain. The upper curve and black dots show excellent agreement between infarction transmurality calculated from the estimated DHE images at end-diastole and end-systole, respectively, for different myocardial segments. The lower curve shows circumferential strain with very good correlation with MI transmurality (more negative strain means better contractility).

CONCLUSIONS: The developed technique generates cine DHE images that show both viability and wall motion information. The good correlations between myocardial thickening measured from the DHE and cine images, and between MI transmurality and strain show the capability of the generated images for predicting regions of limited contractility and the effect of the MI size on the heart function. The generated images are useful for comprehensive evaluation of the patient's condition and treatment options (e.g. determining candidates for revascularization therapy based on contractility reserve and MI transmurality), as well as for differentiation between gadolinium recess in the muscle and actual scar, a process that is usually performed by comparing cine and DHE images side-by-side. Future work includes investigating techniques for minimizing error propagation between consecutive timeframes, a typical issue in OF computation, and applying the developed technique on a large number of patients with different degrees of MI.

REFERENCES:[1] Circulation; 104:2838-42; [2] Int J Comp Vision; 12:43-77; [3] Lecture Notes Comp Sci; 1065:174-83; [4] IEEE Trans Visual Comp Graph; 3:228-44; [5] IEEE Trans Imag Proc; 18:2385-2401; [6] Magn Reson Med 42:1048-60.