Assessment of Global Cardiac Function from Tagged Magnetic Resonance Images. Comparison with Cine MRI

Abram Makram[1], Ayman Khalifa[1], Hossam El-Rewaidy[2], Ahmed Fahmy[2], and El-Sayed H. Ibrahim[3]
[1]Helwan University, Cairo, Egypt, [2]Nile University, Cairo, Egypt, [3]University of Michigan, Ann Arbor, MI, United States

Introduction: Cine MRI images play an important role in evaluating global parameters of the cardiac function (e.g. LV mass (LVM) and ejection fraction (EF)) as they show the myocardial borders clearly, and hence, provide the ability to segment the myocardium accurately. MRI tagging is a technique that is mainly used for evaluation of regional heart function, e.g. myocardial strain, by assessing the taglines deformation during the cardiac cycle. Acquiring both cine and tagged MRI images for evaluating the heart's global and local functions is inconvenient to the patient due to the requirement of multiple breath-holds and long scan time.

A method has been recently proposed for removing the taglines in the tagged images [1], which would allow for using the processed images for deriving measures of global heart function. The method depends on removing the harmonic peaks in the k-space by applying an optimal bandstop filter. The drawback of this technique is that the bandstop filter is designed at diastole, and therefore does not account for the taglines deformation that occurs during the cardiac cycle. Also the resulting images from this technique have low myocardium/blood contrast, which makes myocardial segmentation a challenging task. In this study, we present an improved detagging method by designing an optimal bandstop filter for each timeframe, then apply a contrast enhancement technique [2] for accurate segmentation of the myocardial boundaries.

Methods: Eleven human subjects were imaged on a 3T MRI scanner using cine and tagging sequences. The acquired tagged images consist of three short-axis (SAX) slices (basal, mid-ventricular, and apical) and one long-axis (LAX) slice with 21 timeframes for each slice. The cine images consisted of 9 parallel slices with 21 timeframes, each with slice thickness of 5 mm and no gabs in-between the slices. The cine images were analyzed to calculate global parameters of cardiac function using commercially available Diagnosoft VIRTUE package, which were used as the gold standard for evaluating the performance of the proposed method.

Figure 1 shows the flowchart of the proposed method. The mean shift algorithm (MSA) [3], a cluster analysis technique, was used for detecting the harmonic peaks locations without prior knowledge about the number of peaks. After applying the MSA technique, the resulting partitioned images have one harmonic peak in each cluster. Each harmonic peak was modeled with a 2D symmetric Gaussian function using principal component analysis (PCA) to maintain sufficient image details [1]. Figure 2 shows the clustered peaks, location and shape of the Gaussian models for all harmonic peaks in the k-space, designed bandstop filters, resulting detagged image after applying the bandstop filters (removing the taglines), and final image after contrast enhancement using the local standard deviation (LSD) method [2].

The LSD contrast enhancement method is based on the fact that the tagging pattern decays rapidly in the blood pool due to the blood flow, while it remains in the myocardium until late-diastole. Specifically, an LSD map I_σ is estimated in the neighborhood of each pixel of the original tagged image I_t as follows: $I_\sigma(x,y) = \frac{1}{24}\sum_{i=x-2}^{x+2}\sum_{j=y-2}^{y+2}[I_t(i,j) - m(x,y)]^2$, where $m(x,y)$ is the local mean at $I_t(x,y)$, defined as: $m(x,y) = \frac{1}{25}\sum_{i=x-2}^{x+2}\sum_{j=y-2}^{y+2} I_t(i,j)$. The final detagged image with contrast improvement, I, is given by: $I(x,y) = I_D(x,y) * I_\sigma(x,y)$, where I_D is the detagged image before contrast enhancement.

After detagging and contrast improvement of the images of all slices, the myocardial contours were manually segmented. The triangulation technique [4] was used to reconstruct an LV model after rotating the long-axis slice around the cardiac axis with small angles to make a grid of points between the SAX slices. The correlation between the LVM and EF measurements calculated by both the proposed technique and by Diagnosoft VIRTUE software was then computed to evaluate the performance of the proposed enhancement method.

Results: Figure 3 shows mid-ventricular SAX tagged images both at end-diastole and end-systole. The band-stop filters in the two images are slightly different as the design is optimized per each slice. The papillary muscle is distinguished form blood after improving the contrast. The results showed good correlation between LVM and EF measurements from the detagged and cine images. Although good agreement was observed, LVM showed stronger correlation than EF (R=0.97).

Conclusions: A method is presented for estimating global measures of the heart function from the tagged images. The results showed good correlation with those from the cine images. Despite the need for evaluating the proposed method on a large number of patients with different heart diseases, the developed technique would help reduce scan time by allowing for obtaining both regional and global heart function measures from one dataset of images.

References: [1] IEEE-ISBI 2007, 364-7. [2] ISPHT 2012,1-4. [3] IEEE-TPAMI, 17:790-9. [4] IEEE-EMBC 2014,1-4.

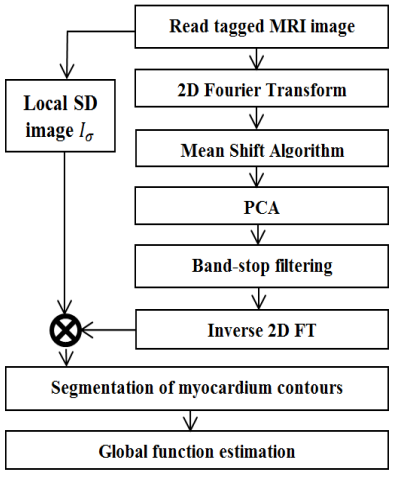

Fig 1. Flowchart of the proposed method.

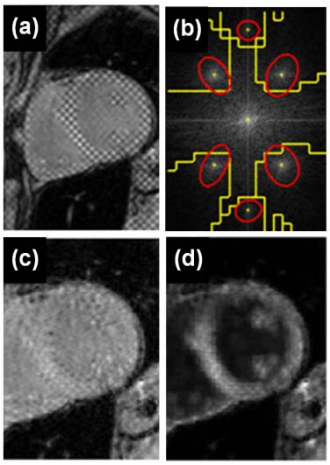

Fig 2. The proposed technique. (a) Original tagged image. (b) k-space showing detected harmonic peaks and customized filters. (c) Image after applying filters. (d) Image after contrast enhancement.

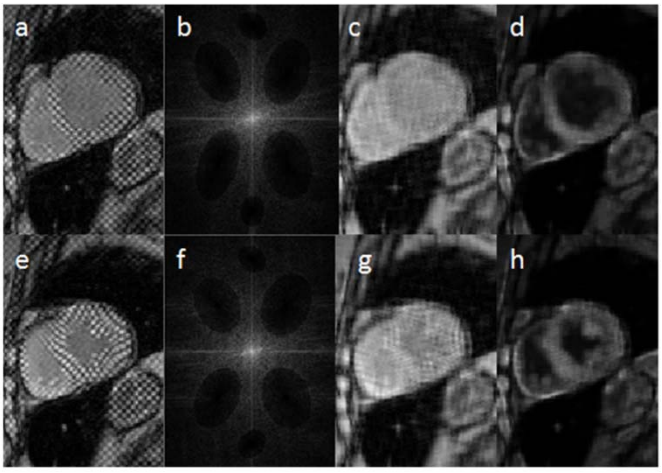

Fig 3. The top and bottom rows show the same mid-ventricular slice at end-diastole and end-systole, respectively. (a,e) Original tagged images. (b,f) k-spaces showing filters location. (c,g) The resulting images after applying the band-stop filters. (d,h) Final detagged images with contrast enhancement.