Inline generation of tagline density maps for radial strain quantification from circular MR tagging

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Purpose: Heart failure is a major cause of death and driver of health care costs in the developed world. Many cardiac diseases result in altered myocardial contractility. A key parameter of cardiac function is the radial strain of left ventricle (LV), typically measured by myocardial tagging. Polar tagging patterns have recently been proposed and implemented[1]. Having tags in the polar coordinate framework not only adapts well with shape of the LV motion, but also facilitates processing and analysis of tagged images [2]. In this work we present a fast reconstruction technique to produce inline density maps of the LV together with circular tagging that become available on the scanner console immediately. This density map is inversely related to the radial strain.

Methods: Circular tags are represented in the form of a localized annulus in k-space (Fig.1) [1]. Myocardial deformation changes the compression of the underlying tag pattern over the myocardium causes widening of the annular ring in the spectrum domain. The strain can be evaluated simply by finding the most prevalent spatial frequency of each region in k-space which shows the local density of taglines for that small area. Considering *L* and *L'* represent a specific length such as the distance between two successive taglines in the radial direction, before and after deformation, the radial strain is calculated through the following equation [2]:

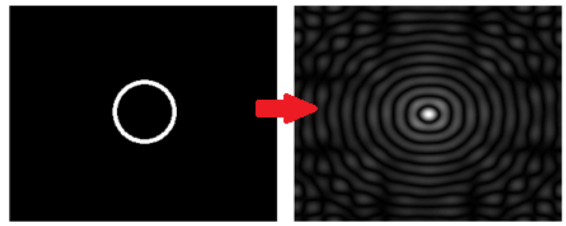

Figure 1. Relation between position of a point in frequency domain(k-space) and corresponding result in image domain for a ringed shape

$$\varepsilon = \frac{L'}{L} - 1 = \frac{K}{K'} - 1$$

Clearly, these lengths are inversely proportional to the K and K'. In circular tagging the primary *K* is almost constant for the entire tagged region. This frequency can be simply derived from the highlighted ring in the K-space of the first frame. Having this fixed *K*, the aforementioned equation reduces the strain calculation problem to the calculation of local *K'* in the following frames. This density map is generated by application of a series of narrow bandpass ring shape filters in the K-space and using 2D correlation of the reconstructed images with the original image.

All processes are embedded in the reconstruction chain of the MR machine (Siemens TIM Avanto and TIM Trio), using the ICE programing environment, to provide the strain maps within a few seconds after the acquisition. MR parameters were as follows: 280 mm FOV, 6mm slice thickness, TE/TR= 3.6/58.08 ms, 250 Hz/pixel bandwidth, 12° flip angle, and 184x192 matrix size.

Results: Figure 2 shows three frames of a cine acquisition of a short axis view of the LV and corresponding density map. Hot colors in the image show areas in the LV which are weighted mostly by higher spatial frequencies. Conversely, cold colors represent dominance of low frequencies in those regions. The reconstruction time for density maps and inline processing depends on the size of the image. In this study, each density map frame took around 14 seconds to be produced.

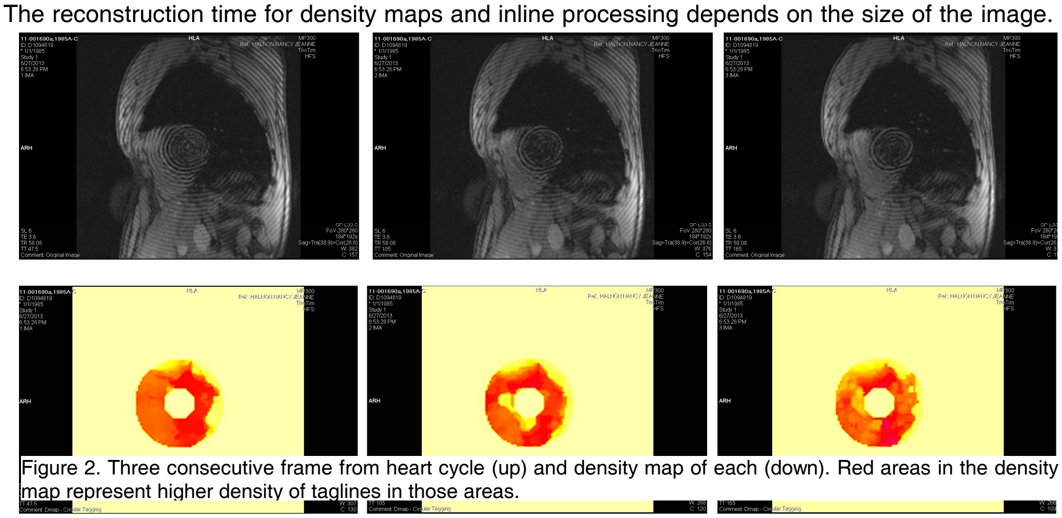

Figure 2. Three consecutive frame from heart cycle (up) and density map of each (down). Red areas in the density map represent higher density of taglines in those areas.

Conclusions: this work demonstrates our preliminary results on inline reconstruction of radial compression maps of the LV, based on circular tagging.., The proposed method is independent of tissue tracking and should provide a quick and convenient parametric functional tool. Clinical validation is ongoing. .

[1] A. Nasiraei-Moghaddam and J. P. Finn, "Tagging of cardiac magnetic resonance images in the polar coordinate system: Physical principles and practical implementation," Magn Reson Med, Jun 26 2013.

[2] A. N. Moghaddam and J. P. Finn, "Accelerated circumferential strain quantification of the left ventricle using CIRCOME: simulation and factor analysis," 2008, pp. 691604-691604-8.