Real-Time M-Mode MRI Monitoring of Regional Wall Thickening

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Introduction

Diagnostic quality ECG monitoring for ischemic changes is not possible in the MR environment due to the magnetohydrodynamic effect. However during MR guided cardiovascular interventional procedures or during stress testing cardiac function should be monitored for possible ischemic changes or dysynchrony. Cardiac function can be assessed in real time by 2D MR imaging and assessed visually, or displayed as m-mode data [1,2] to enable assessment of the temporal history as well. The m-mode display and resulting measurements could then be interleaved with other types of acquisition and incorporated into a real time interface for scanner control such as described in [3-5]. This method has been shown to be feasible [2] for assessment of area ejection fraction (EF). We expanded this method for an automatic measurement of local wall thickness and percent wall thickening. Automated methods of assessing wall thickness in real time could then provide a platform for computer assisted change detection during interventional procedures or stress testing.

Methods

Short axis real time images were acquired in three healthy subjects midway between the mitral valve plane and the papillary muscle level during free breathing with a Siemens Sonata 1.5 T scanner (Siemens Medical Solutions, Erlangen, Germany) using a TrueFISP (SSFP) sequence, TE/TR/Flip angle 0.87/1.74/60º, FOV =160x380 mm^2, matrix 88x128, GRAPPA acceleration x 2, slice thickness 8 mm, temporal resolution 54 ms, 128 frames.
For the m-mode MR creation the user defines the center of the left ventricle on the short axis slice. Four equiangular projections through the ventricle are then defined as m-mode projection beams, intersecting the ventricle in 45 degree segments. The image intensity along each beam ($M_{i,t}$) is then plotted as a function of time (Figure 1B). In order to increase the number of grid points, as well as for smoothing, a bilinear interpolation is performed. To detect the epicardial contours an active contour model ('snake' algorithm) [6] was used. The active contour model minimizes an image energy function. This energy function $E=\lambda E_{int} + \gamma E_{ima}$ of the snake model is expressed in terms of external, constraint forces E_{ima}, depending on the image and of internal constraint forces E_{int}, depending on the shape of the contour. E_{int} is the weighted addition of two terms based on the first and second snake derivatives representing the elasticity and bending forces. E_{img} consists of a linear combination of the image (Sobel) gradient in vertical direction and low pass filtered zero-crossings. In the applied open snake model the coordinate values in horizontal axis consist of integer numbers representing the time point of the m-mode projection, and these values are fixed. Only the position value on the vertical axis of a snake point can move. For snake initialization the endocardial contour is translated in the direction of the expected epicardial contour. Minimizing the energy function causes the active contour to converge. The wall thickness for each time point is calculated as the distance between the endocardial position value and the epicardial position value.

Contours were displayed on the MRI m-mode for visual assessment of accuracy (Fig. 1B). Wall thickness based on the calculated contours (Fig. 1 C1, C2) was also compared with manually drawn contours as an initial validation procedure.

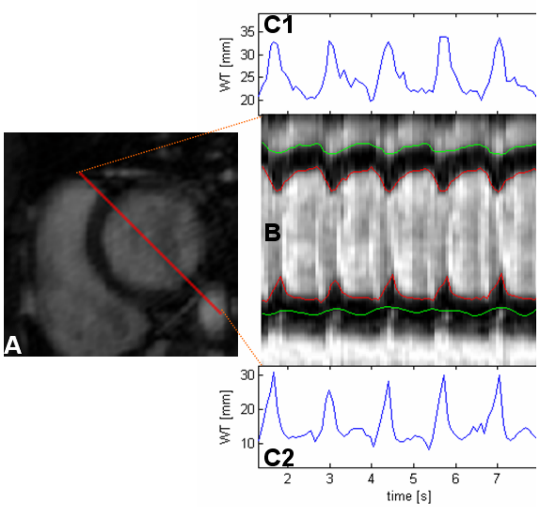

Figure 1: A) Projection line B) MRI M-Mode image, with automatic contours C1) Wall thickness for upper (in m-mode image) myocardium C2) Wall thickness for lower (in m-mode image) upper myocardium

Volunteer	Min Wall thickness	Max Wall thickness
1 (myocardium/lung)	5.51mm +/- 0.70mm	16.53mm +/- 0.74mm
1 (Septum)	5.13mm +/- 0.49mm	9.86mm +/- 1.26mm
2 (myocardium/lung)	6.15mm +/- 0.68mm	15.54mm +/- 0.68mm
2 (Septum)	5.3mm +/- 0.9mm	8.6 mm +/- 0.9mm
3 (myocardium/lung)	9.6mm +/- 0.6mm	15.9 mm +/- 0.5mm
3 (Septum)	3.5mm +/- 1.7mm	10.2mm +/- 1mm

***Table 1**: Average and standard derivation over all cardiac cycles in one m-mode series minimum/maximum wall thickness*

Results

The active contour model was tested on twelve MRI m-mode series (4 projections in each of 3 subjects). The visual qualitative inspection of the MRI m-mode-derived contours on the MRI m-mode display showed good correspondence. Average regional wall thickness was in the range from 7.1 – 11.8 mm as expected for normal wall thickness, minimum and maximum wall thickness is shown in Table 1. In general good correlation between the manual and automated contours was found, with the exception of some points in late diastole where rapid wall motion made manual identification of contours difficult.

Discussion

We have shown the feasibility of a real time method for regional wall thickness assessment. Improvements in temporal resolution in real time imaging could potentially improve the smoothness of the wall motion assessment. Also in cases where there is poor epicardial contrast to the myocardium additional constraints based on neighboring m-mode projections may be necessary to automatically extract the epicardial contour using this method.

References

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