Real Time Ejection Fraction Monitoring With M-Mode MRI

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Introduction

Monitoring the ECG for ischemic changes during dobutamine stress testing or an MR-guided intervention is not possible in the MR environment due to the magnetohydrodynamic effect. However, wall motion and global cardiac function can be assessed in real time by MR and interleaved with other types of MR acquisitions during the procedure. One approach to monitoring for ischemic changes therefore would be to qualitatively assess wall motion in the images as they are acquired. However, in the time gaps where the physician cannot view the functional images (during ramp-up of dobutamine dose, or while placing a catheter for example), it would be useful to have a measure of cardiac function automatically determined and provided as continuous feedback.

We hypothesized that converting real time MR to an m-mode (motion mode) representation analogous to echocardiography [1] would allow (a) a simple continuous display of cardiac function and (b) simplify real time segmentation and automatic extraction of ventricular function parameters. Such an m-mode display could then be incorporated into a real time interface for scanner control [2-4].

Methods

Short axis real time images were acquired in three healthy subjects during free breathing with a Siemens Sonata 1.5 T system (Siemens Medical Solutions, Erlangen, Germany) using a TrueFISP (SSFP) sequence, TE/TR/Flip angle 0.87/1.74/60, FOV =160x380 mm2, matrix 88x128, grappa 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 a single short axis slice (Figure 1a). 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. In $M_{i,t}$ we detect the endocardial contours using a modified horizontal 1D- 'Canny' Filter [5]. Smoothing is performed using a 1D Gaussian with $\sigma=1$. The gradient calculation is based on the second derivation of the Gaussian above. The 'Canny Thresholds' are estimated depending on the histogram of $M_{i,t;}$ we assume that 75% of the pixels are not belonging to the heart wall.

The distances between the detected endocardial contours are then calculated. The maximum distances (as a function of time) in each projection is taken as the LV end-diastolic (ED) diameter, while the minimum distances are taken as the end-systolic (ES) diameters. To estimate the ejection fraction in the slice (EF) the area of the ventricle is computed at ED and ES for each heartbeat using the area enclosed by the 8 vertices of the endocardial contour. As an initial validation, the m-mode–derived contour data were superimposed on the real time images and viewed as a cine-loop for visual confirmation. Contours were also displayed on the m-mode display for visual inspection (Figure 1b).

Results

The visual qualitative inspection of the m-mode-derived contours on the m-mode display (Fig. 1(b)) showed good correspondence. Average area EF for the subjects was in the range 55-70% as expected for normal EF. Beat to beat variation in EF was in the range of 2-9%.

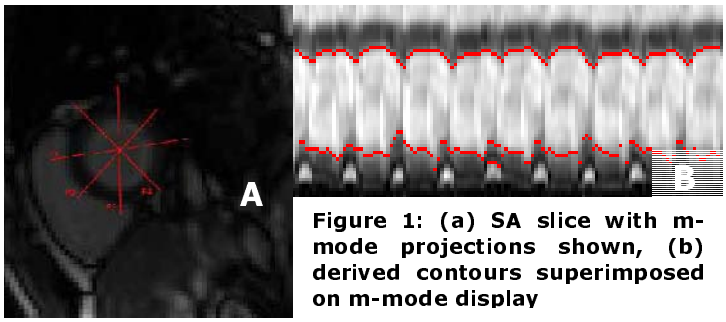

Figure 1: (a) SA slice with m-mode projections shown, (b) derived contours superimposed on m-mode display

Conclusion and Further Work

The results show the feasibility of a real time method for global LV function assessment that can be combined with stress testing or interventional procedures. Integration into a real time environment using 1-2 slices for function monitoring and additional temporally interleaved slices for procedure guidance would be feasible [3-4]. Future work will include further validation against manually drawn contours, determination of spatial and temporal resolution required to allow sensitive detection of clinically relevant changes in EF, and development of change detection algorithms. In addition, extension to epicardial border detection will allow real time monitoring of wall thickening.

References

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