New Approach for Patient-Specific Estimation of Cardiac Motion Due to Respiration

F. B. Punzalan[1], T. Sato[1], T. Okada[2], S. Kuhara[3], K. Togashi[2], and K. Minato[1]
[1]Graduate School of Information Science, Nara Institute of Science and Technology, Ikoma, Nara, Japan, [2]Department of Diagnostic Radiology, Kyoto University Hospital, Kyoto, Japan, [3]MRI Systems Division, Toshiba Medical Systems, Tochigi, Japan

Introduction

Respiratory motion is one of the major limiting factors in coronary magnetic resonance angiography. In dealing with this, most gating approaches involve navigator echoes [1] that monitor the superior-inferior (SI) motion of the diaphragm dome during acquisition and use a fixed tracking factor to describe the cardiac motion [2]. There is however a wide variation in tracking factor between individuals which requires patient-specific calibration [3].

In this study we describe a quantitative estimation of respiratory motion of the heart. Coronal cardiac 2D MR images were acquired for 7 subjects during free breathing and the motion of the right hemi-diaphragm were measured and correlated to the upper and lower part of the heart. We showed that there is high correction factor variability between the upper and lower part of the heart as well as between subjects in the SI direction.

Materials and Method

The motion correction factor was measured for 7 subjects where 2 series of 60 ECG gated coronal chest images were acquired per subject. All images were taken using SSFP sequence in free breathing with TR = 3.2 ms, TE = 1.6 ms, slice thickness = 8 mm, acquisition matrix 160x128, reconstructed matrix size = 320x256 on a 1.5T Excelart Vantage™ MRI scanner (Toshiba Medical Systems, Tochigi, Japan).

The motion of the superior left (upper) and inferior right (lower) portion of the heart were tracked and correlated to the diaphragm movement for each dataset. To track the SI motions, regions of interest (ROI) were placed in a reference image. The ROI in subsequent images were then shifted pixel-by-pixel in the SI direction. After every shift of the image ROI, distance with the reference ROI was calculated using sum of squared difference (SSD). The pixel position which had the smallest distance was assigned as the detected ROI position for every image in the dataset. This procedure allowed the computation of the tracking factor without the use image registration to model the cardiac motion [4].

After tracking the reference ROI position for each image, the motion correlation of both the upper part and lower part with diaphragm motion were computed. The corresponding correlations became the upper and lower part tracking factors and used to describe the difference in respiratory motion-induced translation of different regions of the heart. Validation of the motion tracking was done by visual inspection and manual tracking of the ROI.

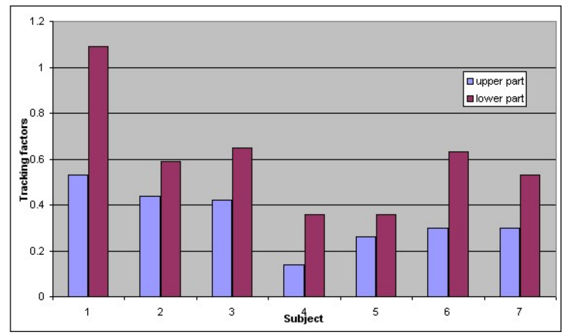

Figure 1. Tracking factors for upper and lower part of the heart for all subjects.

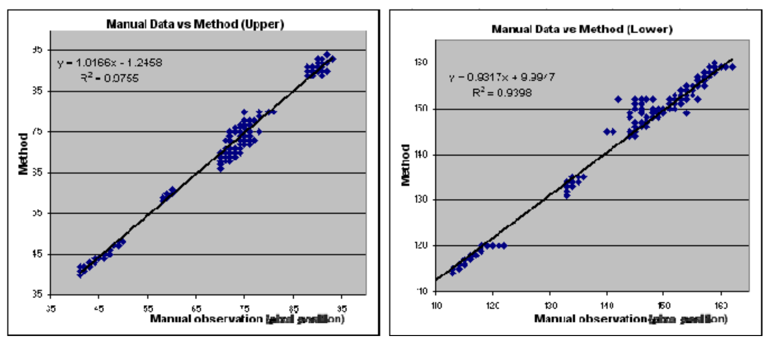

Figure 2. Correlation between the measured positions (pixel pos.) using method and manual observation for upper (left) and lower (right) part of the

Results

A summary of our results showed the wide variations in SI tracking factors between subjects (Figure 1). For the lower part, it ranged between 0.36 for subject 5 and full dependency (1.09) for subject 1. The differences in lower and upper heart motion also exhibited large variations with minimal difference for subject 2 (25%) and substantial for subject 4 (61%). Measured data using the method showed good correlation with manual observation during validation (Figure 2).

Conclusion

It has been shown that there are large differences in the respiration-induced motion between the upper and lower part of the heart (Figure 3). In addition, the subject-specific variation in cardiac motion was observed. These results can be used to describe the respiratory motion of the heart without the use of image registration. It would be helpful in subject-specific tracking without substantial increase in total scan time. Further studies include extending the method to 2D correction for SI and right-left (RL) motion.

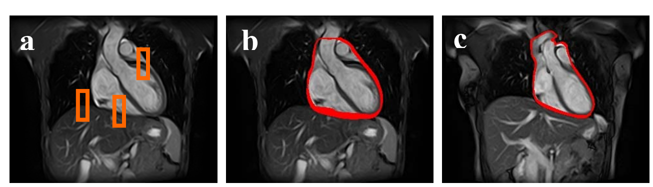

Figure 3. Regions of interest for diaphragm and upper and lower parts of heart (a). The difference in range of 2D motion for subject 1 (b) and subject 5 (c).

References: [1] Sachs TS et al MRM 1994; [2] Danias PG et al Radiology 1997; [3] Taylor AM et al J MRI 1999; [4] McLeish K et al MRM 2002.