

Automated Recognition of Abnormal Left Ventricle Wall Motion

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Introduction: Currently, diagnosis of hypokinetic left ventricle (LV) wall motion is generally based on visual inspection of cardiac magnetic resonance cine images. Studies have shown that this method may be inaccurate, time consuming and suffer from high inter-observer variability [1]. Therefore we propose an algorithm for automated detection of abnormal wall motion that includes inter-subject image normalization and a pattern recognition technique.

Materials and Methods: Imaging data (N=17) were acquired on a 1.5T MRI (GE CV/i Excite) using IR-SSFP short axis (SA) cine sequence; 12/17 patients had regional abnormal wall motion by expert visual assessment. For each of the 17 subjects, a single basal slice was selected for this preliminary study. The recognition algorithm consists of three stages. First, manual input was required to define the LV centre and a reference point on the epicardium. The LV images were normalized by spatially mapping the pixels from Cartesian to polar coordinates, intensity normalization, and labeling standard segments (Fig.1). The essential feature of the cardiac images is the radial wall motion; therefore the analysis is simplified by mapping the pixel intensities from Cartesian (x, y) to polar (r, θ) coordinates. Also, the mapping normalizes the size and shape of the myocardium by equalizing the length of each radial line from the LV centre to the epicardium. Voxel intensities are normalized by setting each to $(x - \mu)/\sigma$, where x is the original intensity, and μ and σ are respectively the intensity mean and the standard deviation (see Fig.1 b & c). Subsequently, segments were defined according to the AHA model [2], with the basal segments 1 to 6 corresponding to the blocks found by dividing evenly the rectangular image (see Fig.1d & h). For each segment, the resulting normalized images for different cardiac phases were concatenated in a column image (Fig. 2a & c). Averaging across polar angle within each segment produced intensity plots with peaks for the blood pool at each phase. The change in peak width across phase indicates wall motion (Fig. 2b). For each segment, correlation coefficients CC_t ($t = 1, 2, \dots, T$) between mean values of the first phase ($t=1$) and all the other phases were computed (Fig. 2d), where T is the maximum phases. The correlation is generally higher when the wall motion is hypokinetic, and therefore the correlation graphs were utilized for discriminative diagnosis. As a classification criterion for each segment, we calculated the CC_t ($t = 1, 2, \dots, T$) averaged across all subjects with the same assessment (normal or abnormal). Usually, for each segment, the minimum value of the averaged normal CC_t ($t = 1, 2, \dots, T$) falls between phase 6 and 10 and is always lower than the minimum of the averaged abnormal CC_t ($t = 1, 2, \dots, T$). Therefore, the minimum value of CC_t for phases 6 to 10 must be less than a threshold for a segment to be classified as normal. Based on this preliminary training set, the threshold is defined as 0.8 for segments 1, 2, 5 and 0.85 for segments 3, 4 and 6.

Results: Expert visual assessment of segment wall motion served as ground truth to determine diagnostic sensitivity 93.6% (29/31 segments), specificity 78.9% (56/71 segments) and accuracy 83.3% (85/102 segments). The results compare favourably with a previous study [1] wherein the sensitivity, specificity and accuracy were reported for a manual (80%, 76%, 77%) and automatic method (84%, 77%, 79%), respectively.

Discussion and Conclusions: Recent work [1] for regional LV wall motion analysis calculated a measure from regional LV cavity area of the end-systole and end-diastole phases to discriminate normal and abnormal wall motion. Compared with [1], there are several advantages of the proposed algorithm. The difficult problem of endocardial segmentation is avoided. Also, this method finds an appropriate balance between complexity and simplicity, for example the segmental analysis is more robust than pixel-wise estimates and the latter are not expected to provide significantly improved results. However, it is comprehensive in that all phases (instead of end-systole and end-diastole only) were utilized. Further improvements are planned by testing a larger group of subjects, with separate training and validation sets, and more effective methods of classification (e.g. SVM). The results demonstrate a promising method that deserves more extensive validation.

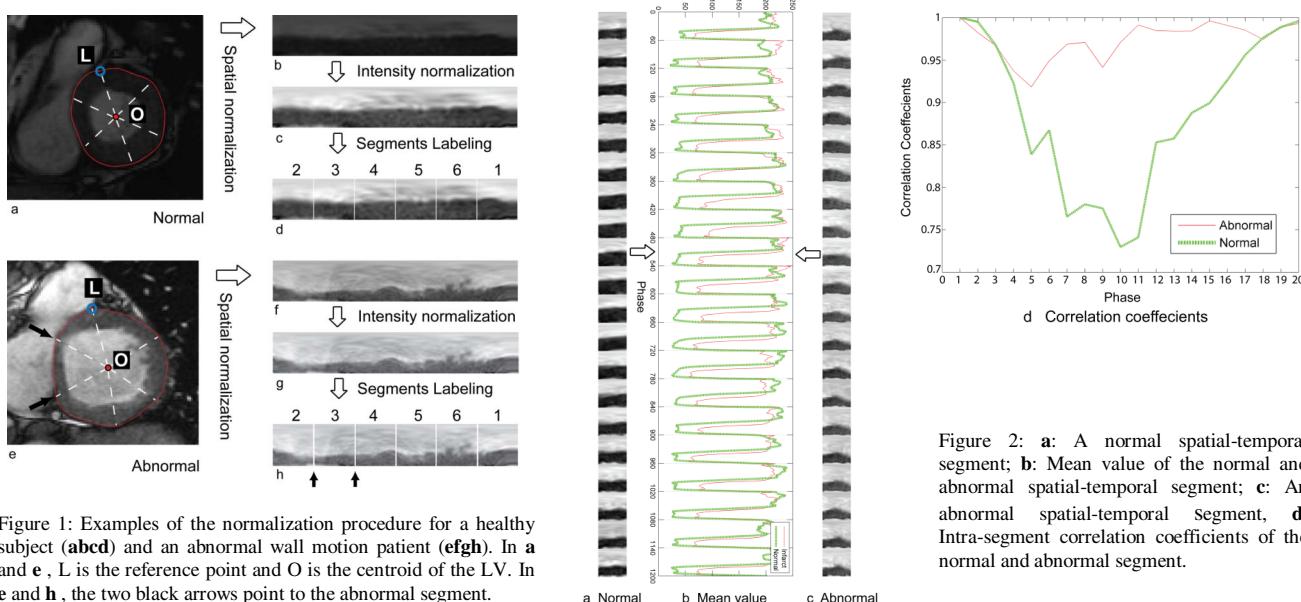


Figure 1: Examples of the normalization procedure for a healthy subject (abcd) and an abnormal wall motion patient (efgh). In a and e, L is the reference point and O is the centroid of the LV. In e and h, the two black arrows point to the abnormal segment.

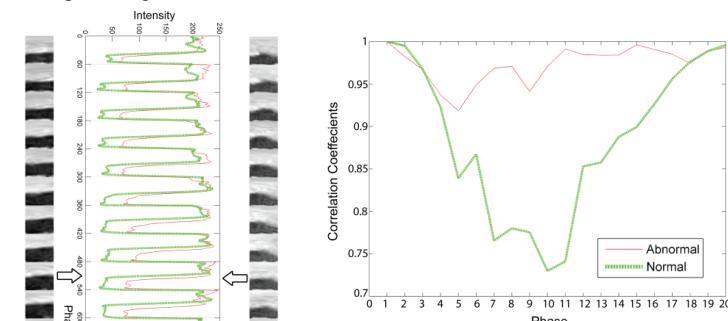


Figure 2: a: A normal spatial-temporal segment; b: Mean value of the normal and abnormal spatial-temporal segment; c: An abnormal spatial-temporal segment, d: Intra-segment correlation coefficients of the normal and abnormal segment.

Reference: 1. Caiani EG, et al., Journal of Cardiovascular Magnetic Resonance, 8(3):427-33, 2006. 2. Cerqueira MD, et al., Circulation, 105(4):539-42, 2002.