Evaluating Left Ventricular Wall Motion Abnormalities using Centerline Trajectory Mapping

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Introduction

Quantification and identification of long axis left ventricular wall motion remains challenging. Visual inspection of echocardiography or cardiac MR images remains the current clinical gold standard [1] due to the lack of effective computer-aid diagnostic software. In this paper, a novel image-processing algorithm called Centerline Trajectory Mapping (CTM) is proposed for quantifying long axis left ventricular wall motion abnormalities. The feasibility of CTM was illustrated on 11 clinical data. The accuracy of the method was also evaluated with echocardiography or myocardial delayed enhancement imaging in clinical data.

Methods

The CTM method tracks the centerline of the left ventricular chamber over time. It entails coil inhomogeneity correction, ROI selection, binary image segmentation, papillary muscle detection, centerline calculation, six-segment division (basal, mid-ventricle, and apical in each side), and map generation (Figure 1). Centerline deviation is determined by relative distance between the centerline in each phase to the reference centerline (e.g. end diastole). In order to differentiate wall motion abnormalities, the local diameter changes are used as a weight to the relative centerline deviation. Red color in the map means normal when CTM<=10 showing small centerline deviation through the cardiac cycle; orange color (10<CTM<=30) means focal wall motion abnormality; and yellow color (CTM>30) means global wall motion abnormality due to the tiny changes in LV diameter because of reduced EF. A total of 11 subjects were enrolled in this IRB-approved protocol including 6 patients (average age: 61±8 years 6males; EF: average = 47% ± 17%) with myocardial infarction and wall motion abnormalities on echocardiography, and hyperenhancement on myocardial delayed enhancement imaging, and 5 healthy volunteers (average age: 52±10 years 3males; EF: 64%± 4%). Two-sample t-test was performed on CTM between healthy and patient groups. Centerline trajectory mapping model utilized standard long-axis (2, 3, and 4 chamber) cine SSFP images (TR/TE 3.6/1.6ms; 224 x 224 matrix; 7 mm slice thickness; 1.25 x 1.25mm, 1 NEX; VPS 20; 20 phases). Two patients and one volunteer also had echocardiograms. A visual comparison of CTM and echocardiography peak strain map was evaluated.

Results

Centerline trajectory mapping was successfully performed in all subjects. Using standard long axis 2D cine SSFP images, CTM analysis demonstrated significant deviation of the centerline during systole in all 6 patients (Maximum CTM amplitude: focal 21.95±4.97 and global 69.78) versus the 5 healthy volunteers (Maximum CTM amplitude 7.48±2.02). The CTM amplitude values of the patients were found to be significantly different (p=0.02) from that of the healthy volunteers (Figure 2) by the t-test. Examples of centerline trajectory mapping on a patient is shown on Figure 3(a) with anteroseptal myocardial infarction and focal hypokenisis. Corresponding echocardiography strain map as shown in Figure 3(b) in 3-chamber view shows decreased strain in the same region (5 vs. 16 and17 in the inferolateral wall). CTM on a healthy subject 2-chamber MR as shown in Figure 3(c) is compared with echo strain map as shown in Figure 3(d) with normal wall motion on both modalities. An example of global wall motion abnormality detected by CTM is shown in Figure 3(e), which is consistent with finds of apical aneurysm of the left ventricle with hyperenhancement pattern on myocardial delayed enhancement imaging (Figure 3f, arrows).

Conclusions

Centerline tracking method can provide a quantitative tool for characterization of focal and global wall motion abnormalities using long axis views of the left ventricle. The proposed method was evaluated with myocardial delayed enhancement imaging and echocardiography with great consistency in wall motion abnormality detection. It does not add any extra scans to existing clinical cardiac MR routine and can be utilized in retrospective studies.

References [1] Mishra MB, et al. European Heart Journal 2002, 23(7):579-585.

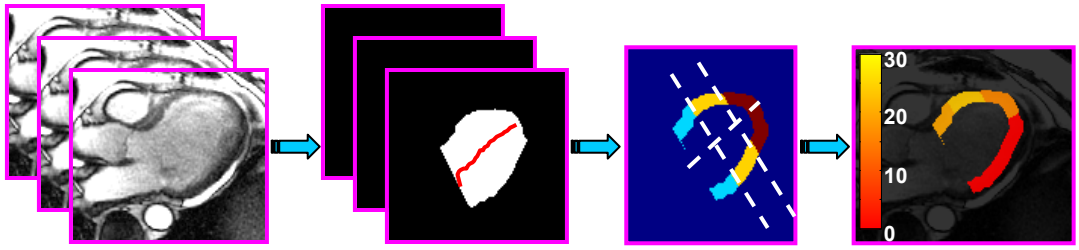

Figure 1. Steps taken for centerline trajectory mapping in a healthy subject. Based on cine SSFP images: inhomogeneity correction, ROI selection, binary image segmentation, convex hull detection, centerline calculation, six-segment division, and map generation were implemented. Red = normal, orange = focal wall motion abnormality, and yellow = global wall motion abnormality.

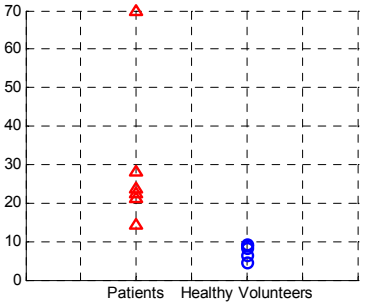

Figure 2. Welch two-sample t-test shows significantly different (p=0.02) from that of the healthy volunteers Triangles are patients, and circles are healthy volunteers. Y-axis is the weighted relative centerline deviation from CTM.

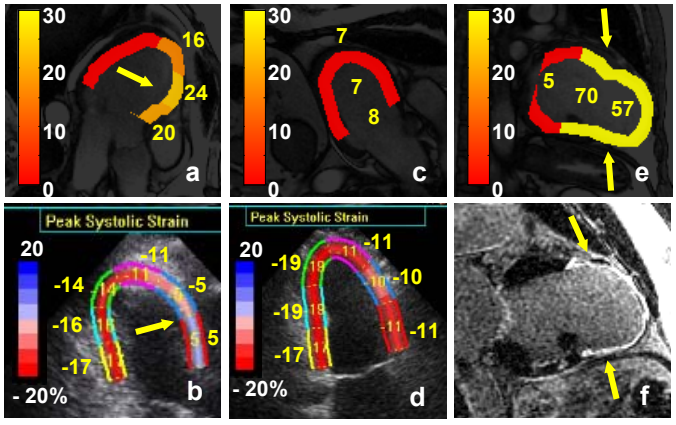

Figure 3. Centerline trajectory mapping is shown on a patient (a) with anteroseptal myocardial infarction and focal hypokenisis. Corresponding echocardiography strain map (b) in 3-chamber view shows decreased strain in the same region (5 vs. 16 and17 in the inferolateral wall). CTM on a healthy subject 2-chamber MR (c) is compared with echo strain map (d) which shows normal wall motion. The global wall motion abnormality CTM (e) is consistent with finds of apical aneurysm of the left ventricle with hyperenhancement pattern on myocardial delayed enhancement. imaging (arrows in f). Red = normal, orange = focal wall motion abnormality, and yellow = global wall motion abnormality.