A Novel Centerline Model for Cardiac Long Axis Wall Motion Analysis

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Introduction

Quantification of cardiac wall motion continues to be a clinical challenge. While most techniques have relied on short axis images, long axis images can provide important quantitative information on cardiac wall motion [1]. An efficient and reliable method for cardiac wall motion quantification in the long axis view is needed for routine clinical practice. In this abstract, a chamber centerline-based model is proposed to quantify the long axis wall motion using traditional cine SSFP images.

Methods

The proposed centerline model is composed with six steps as shown in Figure 1: (1) Coil inhomogeneity correction is applied; (2) A ROI containing myocardial tissue is chosen; (3) Within the ROI, a gray image is automatically converted to a binary image; (4) A convex hull is used to include papillary muscle region within the chamber; (5) Centerline position is automatically estimated at each time frame; (6) After choosing a reference cardiac phase (e.g. end of diastolic phase), relative displacement of centerline for each phase is calculated by ($Distance(Centerline_i - Centerline_{Ref})$). Centerline model utilizes 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). To illustrate the feasibility of the proposed method, one healthy volunteer (51-year-old female, EF 63%) and one patient (63-year-old male, EF 38%, anteroseptal myocardial infarction associated with akinesis of the infarct regions with resultant reduction in resting left ventricular function) were enrolled in this IRB-approved study.

Results

As Figure 2 shows, a centerline displacement map is demonstrated in both the spatial dimension (from basal to apical regions) and temporal dimension (from systole to diastole). The color mapping of the displacement vectors is defined with red representing positive displacement and the blue represents negative displacement. The centerline displacement map quantifies where (by the sign of the deviate motion), when (by the temporal dimension), and how much (by the magnitude) the motion changes compared to the reference centerline. In Figure 2a, centerline analysis for a normal volunteer (2-chamber view) showed no big difference of the centerline motion; in comparison, analysis for a patient as shown in Figure 2b demonstrates large positive magnitude suggesting abnormal regional at basal- and mid-anteroseptal section of the LV, which is consistent with anteroseptal myocardial delayed hyperenhancement indicated by the arrows in Figure 3, and consistent with clinical diagnoses of akinesis at the same location. In Figure 4, three positions in base (red), mid-ventricle (magenta), and apical areas (blue) are chosen to plot the centerline displacement versus time (20 phases of the R-R interval). As for the normal volunteer, the centerline displacements are within 5 pixels. For the patient, during systole, the displacements are 7-15 pixels, and indicate abnormal wall motion in the basal and mid-ventricle anterioseptal area as noted on the 3-chamber view.

Conclusions

A novel long axis wall motion quantification model is proposed to provide reliable and feasible solution to cardiac function evaluation for routine cardiac examinations. This model can be used for vertical long axis views (2-chamber) as well as oblique long axis views (3-chamber). Furthermore, this method can be applied on routine MR cine images without need for specialized pulse sequences, and provides quantifiable parameters of wall motion. This method can also be applied for quantification of wall response during stress testing.

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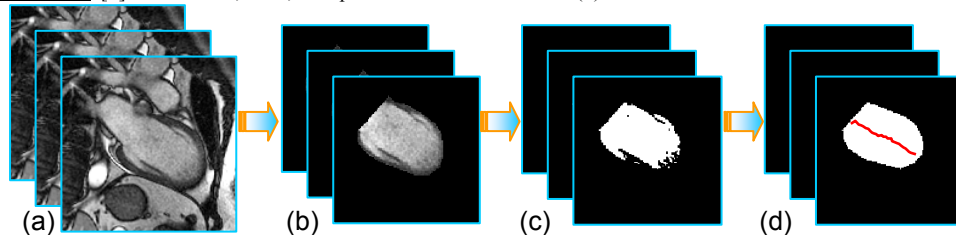[1] M.B Mishra, et al., European Heart Journal 2002 23(7):579-585

Figure 1. Diagram of steps taken for centerline model in a healthy subject. Based on cine SSFP images (a), coil inhomogeneity correction and ROI selection is implemented (b). Binary mask is based on automatic threshold selection (c). Convex hull is calculated at the papillary muscle area and the centerline (red line) is tracked across all time frames (t=1, 2, 3, … 20 for this example) (d).
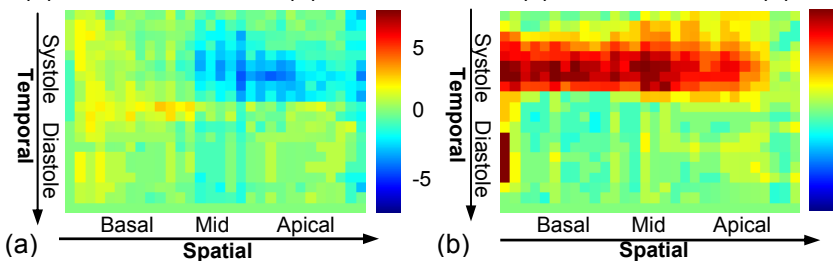

Figure 2. Centerline displacement maps on a healthy subject (a) and a patient with anteroseptal myocardial infarction (b). The x-axis of the map is spatial axis from base (left) to apex (right). The y-axis of the map is the temporal axis from beginning of systolic phase (top) to the end of diastolic phase (bottom). The color in the map means the magnitude of the displacement. The red means positive and blue means negative.

Figure 3. Myocardial delayed enhancement long axis image of the patient with anteroseptal myocardial infarction is shown in hyperenhanced areas (arrows).
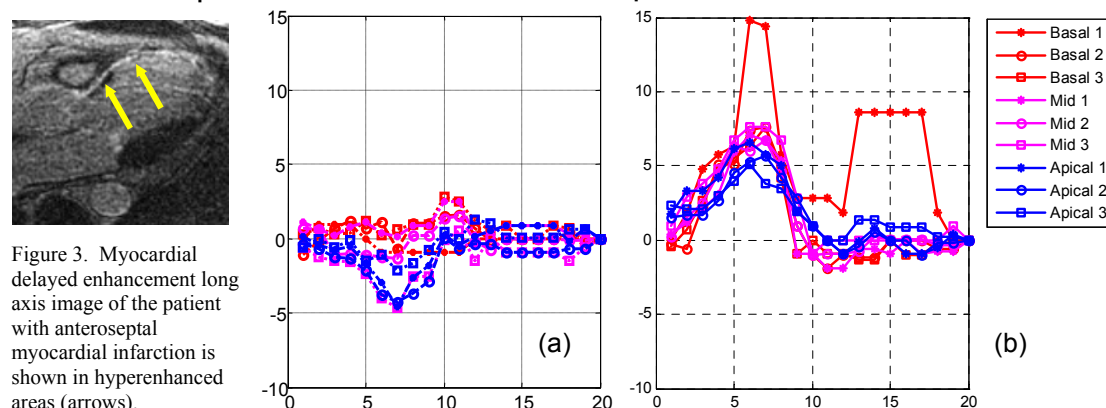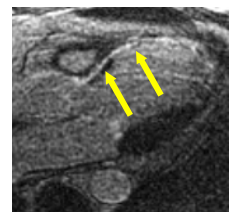
Figure 4. Centerline displacement curves are shown on a healthy subject (a) and a patient (b) with anteroseptal myocardial infarction. X-axis is the time from phase 1 (beginning of systolic phase) to phase 20 (end of diastolic phase). Y-axis is the displacement values for each position at each phase. Red lines are base, magenta lines are mid-ventricle, and blue lines are apical area.