Quantification of Global Hypokinesis in Left Ventricle using Center Point Trajectory (CPT) Mapping

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Introduction

The identification and quantification of diffuse or global left ventricular (LV) hypokinesis is problematic. Visual inspection of cine MR images remains the gold standard for clinical interpretation of images. The diagnosis of subtle global hypokinesis is often only entertained when the ejection fraction (EF) is diminished [1]. We investigate the feasibility of a novel technique called Center Point Trajectory (CPT) mapping that provides not only an improved method for identification of global hypokinesis but also a method for quantitatively characterizing diffuse left ventricular dysfunction. CPT analysis is performed using standard cine SSFP images and does not require specialized pulse sequences (e.g. DENSE or myocardial tagging).

Methods

A polar coordinate map indicating chamber movement with amplitude and angle parameters provides a quantitative way to evaluate wall motion. Image post-processing needs image inhomogeneity correction, ROI selection, binary image segmentation, convex hull detection, polar coordinate contour smoothing, centroid calculation, and map generation. There are three maps: absolute displacement center point map $Dist$, local EF weighted displacement map $Dist/EF$, and local radius change weighted displacement map $Dist/(R\max - R\min)$. A total of 12 subjects were enrolled in this IRB-approved study. CPT analysis was performed on cine SSFP images from 5 patients (average age: 50±11 years; average ejection fraction 36%±4%; 5 males) with mild to severe global hypokinesis as determined by visual interpretation and depressed LV ejection fraction and 7 healthy volunteers (average age: 46±12 years; all normal EF, 5 males). Welch two-sample t-test was used to evaluate statistical significance of the two groups.

Results

CPT mapping examples of one healthy volunteer and two patients are shown in Figure 1. Red line shows systolic center point motion; and blue line, diastolic center point motion. In healthy volunteers the CPT maps (Figure1 1a,b, c) reveal no substantial movement or amplitude of the CPT on all maps (i.e. very little movement of the center point even with EF and chamber radius weighting). The second row shows a patient with heart failure (EF = 30%) and diffused global hypokinesis. In Figure 2a, there is not much movement (i.e. amplitude <3.2mm), in the other EF weighted (Figure1 2b) and chamber radius weighted (Figure1 2c) center point plots there is a substantial deviation of the center point that can be measured in pattern, angle and amplitude. The third row shows a patient with positive T2 inflammation region and global hypokinesis (EF = 35%). All three CPT maps (Figure1 3a-c) show high amplitude CPT movement, which represents global with focal wall motion abnormality. The center point is especially useful for quantification of wall motion in heart failure patients in which wall motion is diffusely abnormal. With colored trajectory using red and blue, both systolic and diastolic phase trajectories can be distinguished. Motion abnormalities can be uncoupled into the two cardiac phases, each with distinctive patterns on the CPT maps. Welch two-sample t-test (Figure 2) reveals statistically difference between the healthy volunteers and patients with global hypokinesis (absolute amplitude, p = 0.030; EF weighted amplitude, p = 0.008; radius weighted amplitude, p = 0.004).

Conclusions

A center point tracking method can provide a quantitative tool for evaluation and quantification of global hypokinesis of the LV. Besides absolute displacement map, EF and radius change weighted maps also provide added value for differentiation of patients with both regional and global wall motion abnormalities. The center point trajectory analysis can be performed on existing data sets without the need for operator-prescribed specific imaging parameters (versus MR special sequences and tissue Doppler). CPT mapping has an advantage in instances where the myocardial wall is thin, which is not uncommon in patients with underlying ischemic heart disease and heart failure.

References [1] L. Fauchier, the American Journal of Cardiology, 93(12): 1504-09 2004.
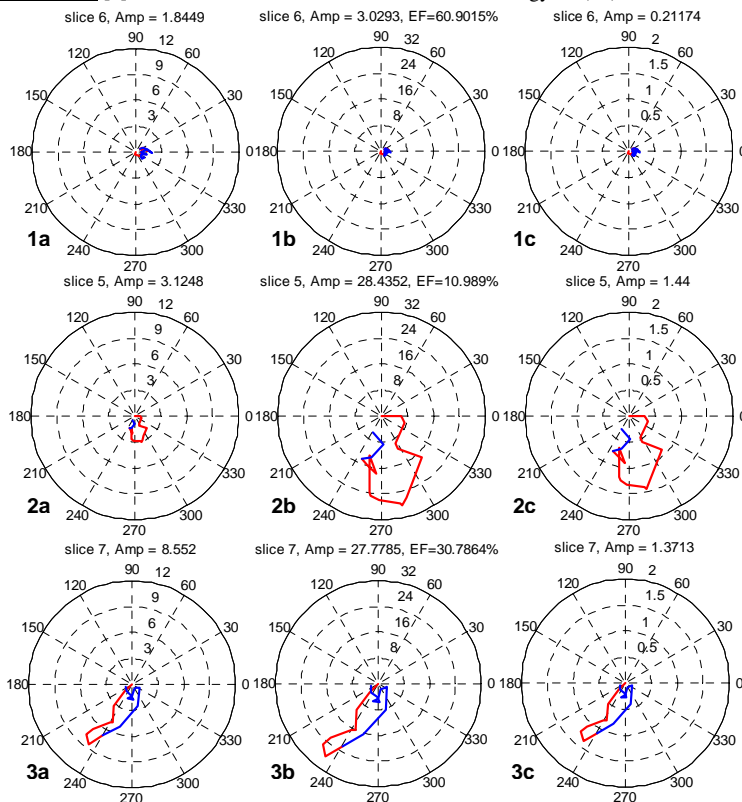

Figure 1. Examples of one healthy volunteer (1a-c) and two patients with global hypokinesis (2a-c), and global but more severe inferoseptal hypokinesis (3a-c). In the left column (a) are the absolute center point displacement maps; in the middle column (b) are EF-weighted center point maps; in the right column (c) are chamber radius-change-weighted center point maps.
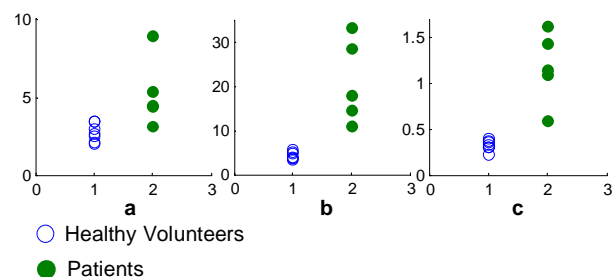

Figure 2. Welch two-sample t-test. (a) are absolute amplitude results, p = 0.030; (b) are results with EF weighted correction, p = 0.008; and (c) are radius change weighted results, p = 0.004.