ABSTRACT

CARDIAC ELASTOGRAPHY

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Cardiac elastography is a promising method for evaluating the functional state of heart muscle. Currently transthoraic echocardiography is used routinely for assessing global and regional myocardial function at rest, with stress echocardiography, used to identify regional ischemia. Clinical diagnosis is based on visually assessed wall motion scores which is semi-quantitative, image quality dependent, and heavily weighted by operator experience. Tissue Doppler imaging, used to assess myocardial muscle velocity, provides quantitative parameters such as longitudinal systolic and diastolic velocity measurements to obtain strain and strain rate data. However, due to narrow-band Doppler phase-shift analysis, they inherit disadvantages associated with Doppler, such as, angle dependence, poor axial resolution, aliasing, and increase in ambiguity of the velocity information.

Limitations with Doppler-derived velocity and strain indices have renewed interest in using B-mode based strain and strain rate measurements. B-mode based strain has the advantage of not being directionally limited. Thus, limitations from Doppler imaging, such as an inability to differentiate between active contraction, simple rotation, and translational motion of the heart wall, are no longer as significant. However, B-mode

speckle-tracking approaches utilize coarser and significantly less sensitive strain estimations when compared to radiofrequency based cardiac elastography.

We utilize radio-frequency signals acquired from clinical ultrasound scanners at frame rates of up to 40/sec. We demonstrate that a frame rate on the order of 10 times the compression frequency is a reasonable compromise to obtain full-field cardiac strain images. A multi-level, hybrid high resolution 2D strain estimation algorithm suited for curvilinear and phased array transducers is proposed to estimate axial, and lateral strains in cardiac tissue. To address the importance of the complex motion of the heart, we have interfaced a finite element based cardiac mechanics model 'Continuity 6' with our 2D ultrasound simulation program, producing simulated 4D (3D + time) RF echo signal data sets in the modeled heart. The impact of lateral shear deformations on strain tensor data, and the use of principal component analysis to improve strain image quality discussed. Principal component analysis provides radial and circumferential strains preferred for clinical diagnosis. Finally, limited evaluations of the techniques proposed in this dissertation are presented on *in-vivo* cardiac data.