Echocardiographic Lagrangian Strain Imaging using Radiofrequency Signals

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Echocardiographic strain imaging is a promising new method for quantifying and displaying the health of cardiac muscle. Accurate cardiac deformation analysis for cardiac displacement and strain imaging over time requires a Lagrangian description of deformation of myocardial tissue. Failure to couple estimated displacement and strain information with correct myocardial tissue structure will lead to erroneous displacement and strain distributions over time. Current clinical approaches utilize speckle-tracking algorithms applied to B-mode images derived from the envelope of radiofrequency (RF) signals. Such approaches are inherently of low spatial resolution, since they require larger data blocks for deformation tracking due to the absence of phase information.

In this work, we developed and evaluated echocardiographic strain imaging based on a Lagrangian framework using RF signals. A Lagrangian tracking algorithm using a polar grid between epi- and endocardial boundaries was developed. This algorithm was validated using a finite element analysis (FEA) based cardiac mechanics model. We then demonstrate that strain images derived from RF signals possess improved elastography signal-to-noise ratios (SNR_e) when compared to that estimated from envelope or B-mode signals, on data from a uniformly elastic tissue mimicking phantom, a cardiac mechanics model and clinical *in vivo* studies. Analysis of the joint probability density function (pdf) of the SNR_e and incremental strain demonstrate accurate estimation of strain with RF signals. Frame rates obtained with current clinical scanners were sufficient to estimate echocardiographic strain. A radial and circumferential displacement and strain estimation algorithm was also developed using our Lagrangian

tracking algorithm and validated using a ANSYS based cardiac wall model and the cardiac mechanics model. Finally, we developed a multi-plane strain estimation algorithm that uses multiple elevational planes to track cardiac deformation using three-dimensional kernels, for improved accuracy in strain estimation.