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Myocardial trajectory estimation for 2D cine DENSE MRI using thin plate splines

Andrew D Gilliam*[1], Xiaodong Zhong[2] and Frederick H Epstein[1]

Address: [1]University of Virginia, Charlottesville, VA, USA and [2]Siemens Healthcare, Atlanta, GA, USA

* Corresponding author

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Objective

To improve the estimation of myocardial strain from cine displacement encoding with stimulated echoes (DENSE) images using the thin-plate approximating spline (TPAS).

Background

A critical stage in the quantification of myocardial strain from raw cine DENSE images is the transformation of Eulerian to Lagrangian displacement. Eulerian displacement, directly measured by DENSE, indicates the prior location of a myocardial element. Lagrangian displacement, generally easier to interpret by cardiologists and radiologists, tracks a myocardial element forward in time. Estimating Lagrangian displacement proves challenging, given the non-uniformly spaced displacement origins and the possibly low signal-to-noise ratio (SNR) of the Eulerian data. In this study, we investigated using the TPAS to accurately estimate myocardial strain from raw DENSE displacement fields.

Methods

Cine DENSE images were acquired in normal volunteers and patients with heart disease using a 1.5 T MR system (Avanto, Siemens), after informed consent and in accordance with protocols approved by our Institutional Review Board. For each dataset, myocardial Eulerian displacement vectors were established as described previously. A unique TPAS was used to define the Lagrangian deformation for each displacement encoding direction at each cardiac phase. Specifically, TPAS functions were represented as a weighted sum of radial basis functions centered on displacement origins minimizing the spline bending energy and the distance to the deformation data. The TPAS requires only a single parameter constraining the allowable displacement approximation error. After TPAS

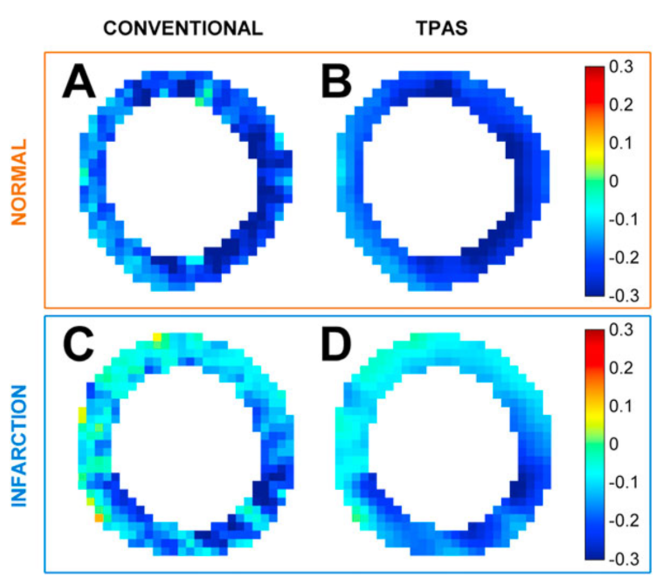

Figure 1
Circumferential shortening maps dervided using the conventional (a, c) and TPAS (b, d) methods for estimating Langrangian displacment trajectories for a normal volunteer (a, b) and a patient with an anterior myocardial infarction (c.d). The overall strain patterns are similar, however, the TPAS technique results in a smoother strain map with higher strain SNR and without individual pixel dicontinuities.

analysis of each encoding direction at each cardiac phase, DENSE analysis proceeded as described previously. To validate the thin plate spline technique, radial and circumferential strain data were estimated from cine DENSE images using both the conventional and TPAS analyses.

Results

Average segmental strain data from the conventional and TPAS analyses correlated well. Figure 1 illustrates typical circumferential shortening derived using the conventional (a, c) and TPAS (b, d) techniques for a normal volunteer (a, b) and a patient with an anterior myocardial infarction (c, d). Overall strain patterns are similar; however, the TPAS technique results in a smoother strain map with higher strain SNR and without individual pixel discontinuities.

Conclusion

This research focused on a critical stage in the quantification of myocardial motion from cine DENSE data, the transformation of directly measured Eulerian displacement into easily interpreted Lagrangian trajectories. The TPAS technique developed in this study proved well-suited to the non-uniformly spaced origins and possibly low SNR of DENSE data, showing good correlation of strain with conventional DENSE analysis while improving noise compensation and eliminating discontinuities.