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Meeting abstract

311 Finite element modeling integration of cardiac MRI structure and function

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Introduction

We have developed a finite element approach to the integration of physiological and biomechanical information into a mathematical model, incorporating data obtained from tissue tagging, *in-vivo* left ventricular (LV) pressure recordings, and *ex-vivo* diffusion tensor MRI (DTMRI). Tissue tagging enables quantitative evaluation of cardiac mechanical function with high spatial and temporal resolution, whilst the direction of maximum water diffusion (the primary eigenvector) in each voxel of a DTMRI image directly correlates with the myocardial fibre orientation [1].

Purpose

To establish model-based registration methods to integrate DTMRI with tagged cine images into a coherent biomechanical model of the LV.

Methods

Previous methods for integrating tagging, DTMRI and pressure recordings in *ex-vivo* passive inflation experiments [2] were extended to *in-vivo* data in dogs acquired at the National Institutes of Health and Johns Hopkins University [3].

Initially, a regular ellipsoid was constructed from estimates of base-to-apex and wall thickness dimensions obtained from MRI in the end-diastolic state. The epicardial and endocardial surface data segmented from the tagged images were used with nonlinear finite element fitting techniques to generate an optimized canine LV geometrical model consisting of 34 nodes with 16 finite elements.

Surface contours of the DTMRI images were manually segmented. Based on these segmented contours, a mask for each DTMRI image was created to exclude pixels that were not within the LV myocardium, such that only the maximum diffusion eigenvectors associated with the LV myocardium were extracted for analysis. Since the tagged images and DTMRI were obtained under different physical conditions (*in-vivo* versus *ex-vivo*), the same heart had a different shape in each dataset.

Myocardial fibre orientations (the maximum diffusion eigenvectors) obtained from DTMRI were incorporated into the LV model using host mesh fitting by minimising the distance between landmark points (DTMRI LV surface data) and target points (the projections of DTMRI LV surface data onto the geometric model). Fibre angles were calculated from the eigenvectors which were warped into the LV model and incorporated into the LV model using a tri-cubic Hermite interpolation function.

In order to simulate the heart cycle, LV pressure recordings, which were temporally synchronized to the MRI tissue tagging data, will be applied to solve the mechanics of the LV. Model parameters, such as mechanical property of

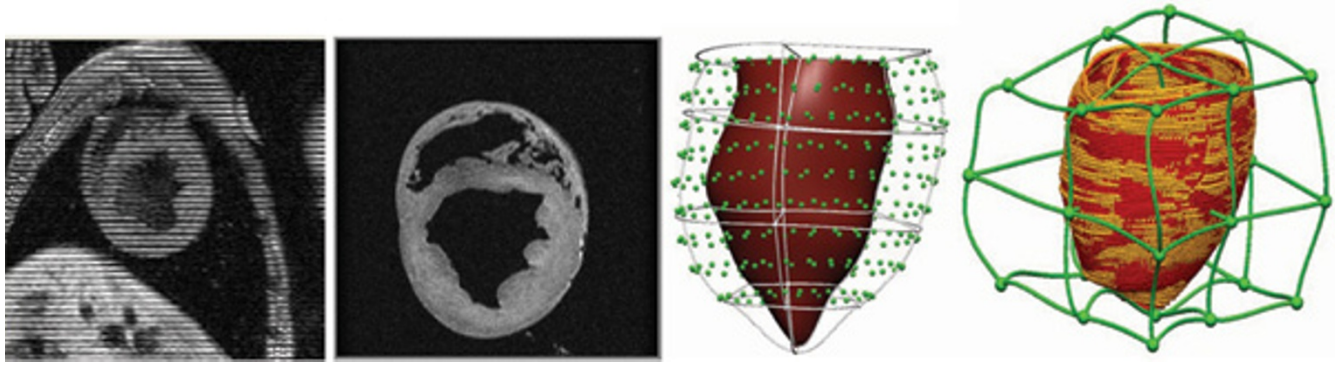

Figure 1
Finite element modeling allows the integration of physiological and biomechanical information from MRI into a coherent model. This enables complex predictions and analysis to be performed. An example of tagging, diffusion and pressure information from a dog is presented. (a) MRI tagged image at end-diastole, (b) DTI image of approximately the same slice, (c) finite element model fitted to tagged image surface points, and (d) DTMRI fibre field warped to match geometric model.

the muscle, will be tuned to reproduce observed deformation and cavity pressure.

Results

Figure 1(c) shows the customized geometric model overlaid with surface data. The epicardial and endocardial surfaces were fitted with an RMS error of 0.33 and 0.26 mm respectively. DTMRI data were registered with the tagging model with an RMS error of 0.47 mm.

Conclusion

This methodology will enable biophysical model parameters, such as the mechanical properties of the myocardium and activation characteristics, to be optimized to match the observed deformation and ventricular cavity pressures. Integrated physiological models for both normal and diseased conditions will then enable the comparison of biophysical parameters influencing cardiac function throughout the heart cycle.

References

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