LEFT VENTRICLE MODEL GENERATED FROM ECHOCARDIOGRAPHIC DATA

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Abstract:

The cardiac cycle consists of two periods: (1) diastole, during which the heart muscle relaxes and refills with blood, and (2) systole, during which heart muscle contracts and pumps the blood out of the ventricle. Numerical modeling of the cardiac cycle can help to evaluate clinical scenarios and outcomes before experimental or clinical applications. In our work, we generated a solid and fluid left ventricle model from echocardiographic data and simulated a full cardiac cycle. Our semi-automatic model generation enables us to simulate cardiac behavior with patient-specific geometries. We simulated the behavior of the heart wall and blood separately, using boundary surface, endocardium, as an interface between solid and fluid. We prescribed displacements to our solid model at the endocardium based on data from echocardiograms, and to our fluid model, we prescribed corresponding velocities at this same surface. We used our solid model with the experimental Holzapfel material model [1] to determine displacements at the epicardium, stresses in fiber, sheet directions, and shear stresses. In our fluid model, we prescribed pressures at aortic and mitral valves.

Key words: echocardiograms, left ventricle mechanics, cardiac cycle, Holzapfel model

1. Introduction

In their research, Verhey and Nathan, used TomTec LV Analysis TEE Software for semi-automatic endocardial border detection, reconstruction, and volume-rendering of the clinical 3D echocardiographic data [2]. During their research they wrote a software which allows visualization of regional deformation of the left ventricle.

In our paper, we present the semi-automatic generation of solid and fluid left ventricle model. The objectives of this work are to show numerical behavior of patient-specific left ventricle geometries and to present usage of Holzapfel experimental material model [1] for modeling heart tissue response to prescribed displacements at endocardium.

2. Methods

From echocardiograms, acquired at three different planes at angles 90°, 150°, and 210°, we manually extract contours, representing the inner and outer wall of the left ventricle, endocardium, and epicardium (Figure 1, step 1). Once we extracted contours we project these lines into 3D space (Figure 1, step 2). Using linear and spline interpolations, we generate points of the model (Figure 1, step 3), and finally, we use these points to generate faces of the model (Figure 1, step 4). We repeat these steps for multiple selected time instances of the echocardiogram. In our work, we start from the beginning of the diastole, and from there we select multiple time instances to cover the full cardiac cycle. Once we created geometries at multiple time instances, we can use them to prescribe displacements and velocities to our solid and fluid models.

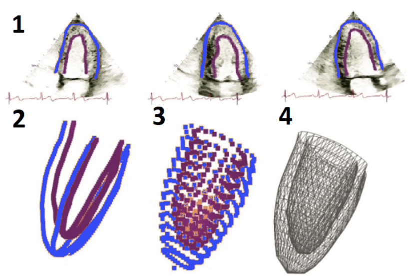

Fig. 1. Left ventricle model generation

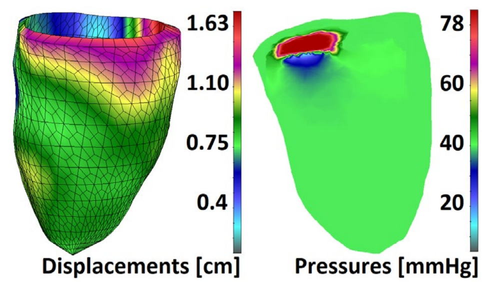

Fig. 2. Displacement field in solid model and pressures in fluid model at 0.6s

3. Results and conclusions

We used Holzapfel experimental material to acquire displacements field at heart wall, which is shown in the Fig 2. With our fluid model, we acquired results that are in good match with referent pressure values (also shown in Fig.2). We can conclude that with our models we can simulate full cardiac cycle with patient-specific geometries.

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