A Novel Approach for Examining Motion and Deformation of Left Ventricle: Finite Element Analysis of 3D Echocardiography Data

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Introduction

Stroke volume, ejection fraction, mass and size of the left ventricle (LV) are very important markers that are used by cardiologists in order to assess the global function and disease severity. For a more comprehensive evaluation, however, displacements, velocities, rotation, twist, torsion, strains, strain rates are investigated. For this purpose, data obtained from 2D/3D echocardiography (echo) devices are often analysed by a dedicated software. In the medical community, it is common practice to examine segmental (regional) values. For example, 3D echo data are analysed by dividing the LV endocardial surface into 16 or 17 areas (segments), which consist of several nodes (vortices) and the nodal values are averaged over the segments [1]. In this study, we aim to analyse LV motion and deformation from engineering perspective by using the finite element method (FEM).

Methods

As a first step, we export the tracked endocardial surfaces from 3D echo data by using the software 4D LV-Analysis from Tomtec Imaging Systems GmbH. The software discretizes the tracked surface over 862 nodes with 1720 triangular elements and enables to export the current coordinates of the nodes from the beginning of the systole to the ending of the diastole. Namely, the deformation state of LV endocardial surface is available at each time frame. From a computational perspective, the exported data is equivalent to obtaining the finite element (FE) solution of contracting LV [2]. Once having the deformation state of the LV at hand, one can calculate any deformation related quantity in a pointwise manner such as displacement along preferred directions, strains, rotation and surface curvature.

Results

A sample of echo data is processed into an FEM software and pointwise displacement distribution along z-direction is demonstrated in Figure 1. The preliminary results indicate that the deformation state of a point might not be necessarily in line with the deformation state of the averaged value over the segment in which the point exists. For instance, although the rotation of the apical segment has positive sign, various nodes on the apical segment might have negative sign.

Discussion

The new methodology enables to disclose local deformation behaviour rather than examining averaged segmental values. Although, the averaged segment values provide useful information and are widely used, looking at pointwise values might enable a more extensive LV assessment, which has not been attracted attention so far. For instance, averaging might be ruling out unusual localized deformations, particularly in pathological cases, which can be only detected through a point-wise distribution.

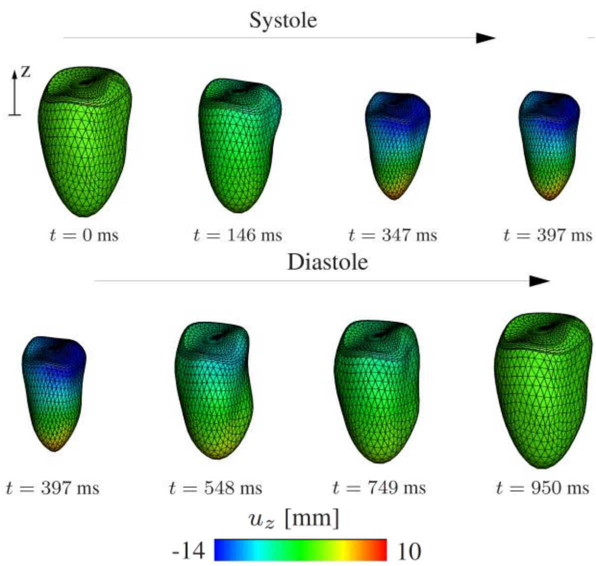

Figure 1: Exported acho data from 4D LV-Analysis Tomtec is processed into FEM framkework. The LV endocardial surface and mitral valve plane are discretized with 1720 triangular elements over 862 nodes. The deformed shape and nodal displacement distribution along z-axis are illustrated during the entire cardiac cycle.

References

1. Lang et al, Journal of American Society of Echocardiography, 28:1-39e14, 2015.
2. Cansız et al, Journal of Applied Mathamatics and Mechanics , 98:2155-2176, 2018

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