EXTENSION OF OUR COMPUTATIONAL MODEL FOR THE LEFT VENTRICLE TISSUE TO INCLUDE HYPERTROPHY

Milos Kojic[1,2,3]

[1] Bioengineering Research and Development Center BioIRC Kragujevac, Prvoslava Stojanovica 6, 3400 Kragujevac, Serbia.
[2] Houston Methodist Research Institute, The Department of Nanomedicine, 6670 Bertner Ave, R7 117, Houston, TX 77030.
e-mail: mkojic42@gmail.com
[3] Serbian Academy of Sciences and Arts, Knez Mihailova 35, 11000 Belgrade, Serbia.

Abstract:

We have recently developed a computational model for passive response of the left ventricle (LV) tissue [1]. The model was formulated in a way to use directly the experimental constitutive relationships, hence avoiding usual parameter fitting for a selected analytical constitutive law. In case of deceases, such as hypertrophy, it is necessary to modify the basic model for healthy tissue to include additional effects to the LV wall response. Here, we extend our computational model by incorporating hypertrophy model according to [2]. There are two types of hypertrophy, eccentric and concentric. The first one is strain-driven due to increased diastolic wall strain which produces serial deposition and addition of sarcomeres in series, with an increase in cardio myocyte length. The concentric hypertrophy occurs due to increased systolic wall stress which causes addition of sarcomeres in parallel, with increase in myocyte cross sectional area and ventricular wall thickening. We here demonstrate the effects of hypertrophy on a simple model of a tissue sample subjected to biaxial loading.

Key words: Left ventricle wall model, experimental constitutive law, hypertrophy model, eccentric hypertrophy, concentric hypertrophy

1. Introduction

Besides enormous efforts to develop computational models for tissue deformation of heart tissue, still there is a need form models improvements. These models are traditionally based on analytical forms of strain energy with certain number of material constants which are obtained by fitting procedures. We have formulated a model by a direct use of experimental constitutive relationships [1]. A challenge remains to include additional effects produced by a disease, such as hypertrophy.

2. Methods

Hypertrophy is represented by deformation gradient [2] $\mathbf{F}^{g} = \mathbf{F}^{c0} + \mathbf{F}^{ec}$, where $\mathbf{F}^{c0}$ represents concentric and $\mathbf{F}^{ec}$ eccentric hypertrophy gradients, respectively. These gradients can be expressed as

$$\mathbf{F}^{co} = \mathbf{I} + \left(\vartheta_{co} - 1\right)\mathbf{s}\times\mathbf{s}, \quad \mathbf{F}^{ec} = \mathbf{I} + \left(\vartheta_{ec} - 1\right)\mathbf{f}\times\mathbf{f} \tag{1}$$

where **f** and **s** are unit vectors of the LV fiber and sheet directions, respectively; and

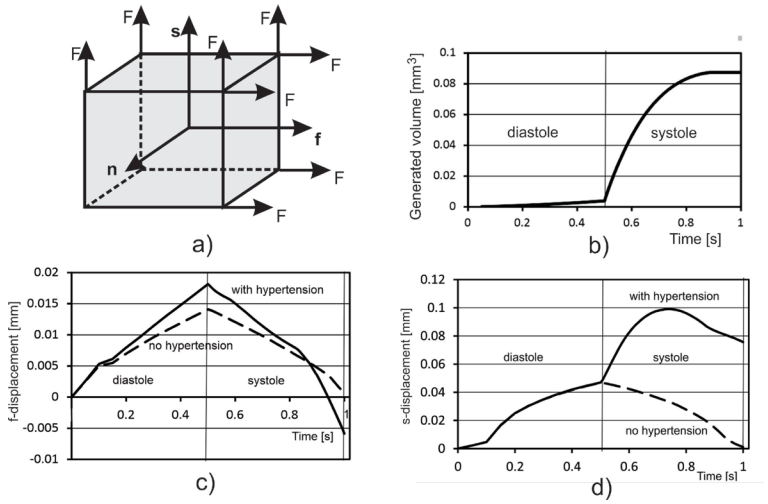

Fig. 1. a) A 3D finite element (with dimensions of 1mm) subjected to biaxial cyclic loading, with both hypertrophy effects; b) Accumulated volume; c), d) Displacements along fiber (f) and sheet (s) directions

ϑ_{co} and ϑ_{ec} are the evolution functions for hypertrophy. Multiplicative decomposition of deformation gradient is employed (as common in inelastic engineering materials), $\mathbf{F} = \mathbf{F}^{e}\mathbf{F}^{g}$ where $\mathbf{F}^{e}$ is evaluated from constitutive law; here, we employ our computational model based on direct use of constitutive curves**.** We illustrate application of the effects on hypertrophy on simple example of biaxial loading of tissue. Results are shown in Fig.1.

3. Conclusions

In this report we extended our computational model [1] by including hypertrophy. Material parameters for hypertrophy given in [2] were modified to emphasize the effects of hypertrophy. The results demonstrate that this extended model can be used in applications.

Acknowledgment: This work is supported by SilicoFCM project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 777119. The research was also funded by National Cancer Institute under the grant U54 CA210181.

References

[1] Kojic M, Milosevic M, Milicevic B, Geroski V, Simic V, Trifunovic D, Filipovic N, *Computational model for heart tissue with direct use of experimental constitutive relationships*, submitted.

[2] Göktepe S, Abilez OZ, Parker KK, Kuhl K, *A multiscale model for eccentric and concentric cardiac growth through sarcomerogenesis*, J. Theoretical Biology, 265, 433–442, 2010.