EXAMINING THE EFFECT OF PARAMETERS ON MECHANOBIOLOGY ATHEROMA PLAQUE GROWTH MODEL

Patricia Hernández-López (1), Miguel Ángel Martínez (1,2), Estefanía Peña (1,2), Myriam Cilla (1,2)

1. Aragon Institute of Engineering Research (I3A). University of Zaragoza, Spain
2. Biomedical Research Networking Center in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Spain

Introduction

Cardiovascular diseases, including atherosclerosis, are one of the main causes of mortality in developed countries nowadays. There is a huge quantity of substances and parameters involved in the process of formation of atheroma plaques, so it is important to understand how each substance and parameter influences the growth of plaques [1].

Therefore, the aim of this study is to analyse the influence of the parameters of a previous computational model of the formation of atheroma plaques in arteries [2], to determine the effect of these parameters in the growth and composition of atheroma plaques. The mathematical model used has a total of 52 parameters, which come from different studies and can be related to experimental or computational analysis. Among the experimental ones, there are some differences between the analysis conditions. Moreover, they come from studies of different species and from different arteries (coronary, carotid or aorta). Finally, some of them have been estimated based on computational results. Therefore, the values of the parameters can have a large variation, so it is relevant to perform a sensitivity analysis of the parameters of the model.

Methods

The geometry has been developed based on that of Olgac et al. [3] as it reproduces the mechanical stimuli that real patients are subjected to that lead to plaque apparition (TAWSS and OSI).

The mathematical atheroma plaque model has been described and published by the same authors [2]. The software COMSOL Multiphysics (COMSOL AB, Burlington, MA, USA) has been used to computationally solve the model.

All the 52 parameters have been increased and reduced by 10% in different simulations in a mono-variant sensitivity analysis. The percentage of change of volume of the plaque due to each one of the substances involved in its growth (foam cells that compose the lipidic core of the plaque, and synthetic smooth muscle cells and collagen fibers, that correspond to the fibrous layer of the plaque) has been analyzed, as well as the variation of the stenosis ratio,

Results

In figure 2, the variation of the volume of foam cells, synthetic smooth muscle cells and collagen fibers is represented in a graphic of parallel bars for the increase and reduction of the considered parameters of 10%.

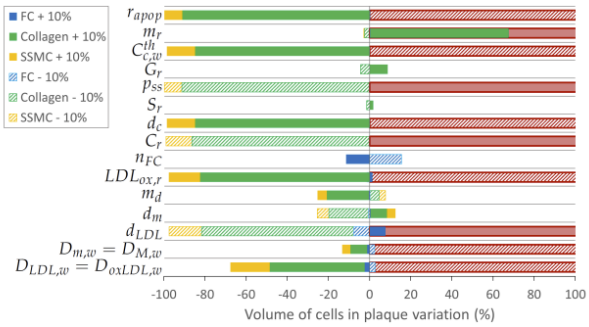

Figure 2.- Variation of the volume of FC (blue color), SSMC (yellow color) and collagen (green color) for the cases of increase and decrease the parameters in a 10% (solid and striped colors, respectively). Bars in red color represent a variation of one of the substances higher than 100%.

Discussion

The variation of the selected parameters carries important variations of the results and, in some cases, the variation can be higher than 100%. In addition, it has been noticed that a variation of foam cells volume derives in more change of the stenosis ratio of the plaque than a change of synthetic smooth muscle cells or collagen volumes, due to their bigger volume. For all of this, it could be interesting to study the vulnerability of plaques by changing the analyzed parameters, knowing how each one of them affects to the volume of foam cells, synthetic smooth muscle cells and collagen fibers in the plaque.

References

1. P. Libby et al. Nature. 473:317-325, 2011
2. P. Hernández-López et al. Frontieres. 9: 690685, 2021.
3. U. Olgac et al. Am. J. Physiol. Heart Circ. Physiol. 294: 909-919, 2008.
4. M. Cilla et al. J R Soc Interface. 11:20130866, 2014.

Acknowledgements

This research was funded by the Spanish Ministry of Science and Technology through research project PID2019-107517RB-I00 and financial support to P. Hernández-López from the grant BES-2017-080239 and the regional Government of Aragón support for the funding of the research project T24-20R.