Coupling a Cell Calcium Network with an Arterial Solid Model

A. Coccarelli[*†], D. H. Edwards[*], D. Parthimos[*] and P. Nithiarasu[†]

[*] Institute of Cancer and genetics, School of Medicine, Cardiff University, Cardiff CF14 4XN, United-Kingdom

[†] Zienkiewicz Centre for Computational Engineering, Swansea University, Swansea SA2 8PP, United-Kingdom, e-mail: P.Nithiarasu@swansea.ac.uk

ABSTRACT

Physiological regulation of blood flow can be subdivided into three primary control domains: (i) rheological conditions imposed by the mechanics of blood flow through variable vascular geometries, (ii) arterial wall contractile apparatus, located within the vascular smooth muscle (SM), and (iii) the endothelium, a monolayer of cells lining the inner surface of blood vessels, which operates as an active interface, that translates and amplifies the electrochemical signalling between domains (i) and (ii). The ability of a blood vessel to adapt to variable rheological requirements, by responding to electrochemical signalling generated by the endothelium, is a fundamental measure of vascular health. The smooth muscle contractile machinery is driven by a complex intracellular calcium dynamics [1, 2].

In the present work we propose a strategy for evaluating the stress response in the arterial wall induced by subminstration of drugs able activate the SM contractile machinery. The contractile state of SM constitutes one side of the non linear relationship between stress and deformation of the vascular structure. In the absence of fluid flow it becomes the only force-generator mechanism. Under these assumptions, we propose to simulate the mechanical behaviour of an arterial ring isolated in a physiological solution and subjected to a drug intervention. For doing this, we have integrated a realistic calcium cell network within an arterial structural dynamics model. For describing the complex calcium dynamics associated with the SM layer, we have used our recently developed methodology [3]. To perform the structural analysis of the arterial wall, a finite element technology based on hybrid elements has been used. The arterial wall is subdivided into media and adventia layers, and for both layers the theory of fibre reinforced material is assumed. Calcium signal from cell network is transferred to finite elements discretization of the media layer by using an interpolation technique based on Radial Basis Function. The methodology proposed in [4] has been adopted for converting the element calcium concentration into active stress. We remark that in this way the inlet calcium signal differs element by element and depends on the resulting cellular coupling. The outcomes of this theoretical study are compared with experimental measurements.

REFERENCES

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