Agent-Based Modelling of the vibration-induced arterial growth

Maha Reda[1,2 *], Christophe Noel [1], Nicla Settembre[3], Jérôme Chambert[2], Arnaud Lejeune[2] and Emmanuelle Jacquet[2]

[1] Institut national de recherche et de sécurité (INRS), Vandœuvre-Lès-Nancy, France
[2] Univ. Bourgogne Franche-Comté, FEMTO-ST Institute UFC/CNRS/ENSMM/UTBM, Department of Applied Mechanics, Besançon, France
[3] Department of Vascular Surgery - Nancy University Hospital, France

Key Words: *Hand-Arm Vibration, Agent-Based Model, Wall Shear Stress, Finite Elements.*

An acute exposure to Hand-Arm transmitted-Vibration can reduce the Wall Shear Stress (WSS) between the blood and the arterial endothelium. Several studies have highlighted that the Low Shear Stress (LSS) could alter the endothelium morphology and functions [1]. After a sustained exposure to vibration, this LSS could cause various vascular pathologies such as the vibration-induced Raynaud's Syndrome. This disorder is characterized by an arterial growth and remodelling potentially induced by an intimal hyperplasia phenomenon.

The proliferation and migration of the Vascular Smooth Muscle Cells (VSMCs) are the keystone of the intimal hyperplasia phenomenon [2]. These biological mechanisms are governed by multiple growth factors secreted by the endothelium after exposure to LSS. Studies have shown that LSS induce the production of the Platelet-Derived Growth Factors (such as the PDGF-AB) leading to an increase of the VSMCs proliferation rate [1]. In our study, an Agent-Based Model (ABM) of the WSS-modulated VSMCs proliferation is presented. The proposed ABM features two types of cell layers: Endothelial Cells, subjected to laminar flow and VSMCs. Literature-derived equations linking the evolution of the SMCs proliferation rate to the WSS values have been used [3]. Three values of WSS were tested: one basal physiological (3 Pa) and two LSS values (1 and 2 Pa). The model is implemented in NetLogo© Software and is on the way to be validated using experimental data issued from biological tests on cultured VSMCs under flow.

Our Agent-Based proliferation model will be adapted to an arterial geometry and coupled with a Finite Element (FE) model that mimics the anisotropic hyperelastic mechanical behaviour of the artery. This mechanobiological model will help in predicting the arterial growth and remodelling induced by the Hand-Arm transmitted-Vibration.

REFERENCES

[1] Ziegler, T., Bouzourene, K., Harrison, V. J., Brunner, H. R., & Hayoz, D. (1998). Influence of oscillatory and unidirectional flow environments on the expression of endothelin and nitric oxide synthase in cultured endothelial cells, *Arterioscleris Thrombosis and Vascular Biology* 18, 686–692.
[2] Newby, A. C., & Zaltsman, A. B. (2000). Molecular mechanisms in intimal hyperplasia. *Journal of Pathology*, *190*(3), 300–309.
[3] Keshavarzian, M., Meyer, C. A., & Hayenga, H. N. (2018). Mechanobiological model of arterial growth and remodeling. *Biomechanics and Modeling in Mechanobiology*, *17*(1), 87–101.