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PII: S0021-9290(16)31319-7
DOI: http://dx.doi.org/10.1016/j.jbiomech.2016.12.026
Reference: BM8059

To appear in: *Journal of Biomechanics*

Received date: 15 June 2016
Revised date: 23 November 2016
Accepted date: 21 December 2016

Cite this article as: Robin Chatelin, Dominique Anne-Archard, Marlène Murris Espin, Marc Thiriet and Philippe Poncet, Numerical and experimenta investigation of mucociliary clearance breakdown in cystic fibrosis, *Journal o Biomechanics,* http://dx.doi.org/10.1016/j.jbiomech.2016.12.026

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Abstract

The human tracheobronchial tree surface is covered with mucus. A healthy mucus is an heterogeneous material flowing toward the esophagus and a major defense actor against local pathogen proliferation and pollutant deposition. An alteration of mucus or its environment such as in cystic fibrosis dramatically impacts the mucociliary clearance. In the present study, we investigate the mechanical organization and the physics of such mucus in human lungs by means of a joint experimental and numerical work. In particular, we focus on the influence of the shear-thinning mucus mobilized by a ciliated epithelium for mucociliary clearance. The proposed robust numerical method is able to manage variations of more than 5 orders of magnitude in the shear rate and viscosity. It leads to a cartography that allows to discuss major issues on defective mucociliary clearance in cystic fibrosis. Furthermore, the computational rheological analysis based on measurements shows that cystic fibrosis shear-thinning mucus tends to aggregate in regions of lower clearance. Yet, a rarefaction of periciliary fluid has a greater impact than the mucus shear-thinning effects.

Keywords: Computational biology, Cystic fibrosis, Mucociliary clearance, Modeling, Rheology, Generalized Stokes equations, Penalization, Grid-particle methods.

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