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Dynamics of Cells in interaction with a substrate using a Level Set method

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ABSTRACT

Cells in living organisms are able to move by themselves in their environment, leading to so called motile behaviour. In other words, cell dynamics in epithelial channels is not only driven by fluid-structure dynamics but is also modified by active interaction provoked by the cell either with other cells or with surrounding channel. Cell motility has been observed many times in vivo. For instance, when microbial infection occurs, defense of the organism involves migration of macrophage cells. Epithelial tissue cells and dermal cells also actively migrate in wound healing process. Another examples are linked to pathological processes such as inflammation which induces leukocytes migration and metastasis propagation due to migration and penetration – through the endothelial barrier – of cancer cells which detach from primary tumour. These are some of many reasons which motivate researchers to understand cell-cell and cell-endothelium interaction during their transport through the blood stream. Latter interaction leads to extravasation, i.e. penetration through the endothelial barrier, which relies on several factors such as cell adhesion properties, flow conditions and role of confinement in capillary geometry. Extravasation comes after a succession of several following steps. Cells (such as leukocytes or cancer cells) begin by interacting with the endothelium thanks to weak bonds related to specific adhesion molecules : these interaction forces induce rolling of cell on endothelium. Then stronger bonds are activated and eventually lead to adhesion of cell on endothelium. Finally, cells can spread and migrate until a suitable site is reached, from where they can extravasate [1].

In this talk, we will present a Level Set model used to simulate cell dynamics involved in extravasation, namely rolling, adhesion and spreading on the endothelium. To do so, we use microfluidic configuration for endothelial channels which allows to take into account confinement and strong surface tension effects [2, 3]. Cells are captured thanks to a Level Set method [4, 5] coupled to a Stokes formulation for the flow. Furthermore, we use various models of adhesive forces induced by cell-matrix interactions.

This is a joint work with Claude Verdier (CNRS - LSP). Numerical simulations are compared with physical experiments conducted on cell dynamics by Claude Verdier's group at Laboratoire de Spectrométrie Physique (LSP), Grenoble, France.

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