Mechanical destruction of tumor cells: experiments, multiscale modeling and simulations

M. O. Steinhauser*†

* Fraunhofer-Insitute for High-Speed Dynamics, Ernst-Mach-Institute, EMI
Eckerstrasse 4, 79104 Freiburg, Germany
e-mail: martin.steinhauser@emi.fraunhofer.de, web page: http://www.emi.fraunhofer.de

† University of Basel
Klingelbergstrasse 80
CH-4056, Basel, Switzerland
e-mail: martin.steinhauser@unibas.ch, web page: http://www.chemie.unibas.ch

ABSTRACT

Besides resection, i.e. the surgical removal of tumors, and chemotherapy, an established treatment in tumor therapy is the use of High Intensity Focused Ultrasound (HIFU). The treatment with ultrasound is based in essence on the destruction of tumor cells by heating. At temperatures above 56 degrees Celsius proteins start to coagulate, causing the cells to go into apoptosis, i.e. cell death. However, the principal of heating cells usually leads to unwanted side effects such as cutaneous burns and damage of healthy tissue and the need of many repetitions of the HIFU sessions, which delimits acceptance of this treatment among patients. Here, exploring the potential of shock waves (instead of ultrasound) for destroying or damaging cancer cells possibly opens a new road for tumor treatment. By way of using only the purely mechanical effects of shock waves rather than relying on heating of cells, it seems possible to destroy or damage the cytoskeleton or the membrane of tumor cells, while at the same time avoiding the negative side effects of HIFU treatment that are connected with heating. Due to the complexity of the interaction of shock waves with soft biological matter, a combined approach using experimental and computational methods is needed. After shock wave treatment, the cells are analyzed for damage and destruction.

Discussing particle-based *coarse-grained* modeling approaches for understanding the damaging or failure of cells' biomembranes and their cytoskeleton network in simulations, the presentation highlights some results of a research initiative towards the possible destruction of cancer cells using laser-induced high energy shock waves. In contrast to fully flexible polymers, coarse-grained models of semiflexible polymer models have received attention in recent years, because such models can be applied to many important biopolymers such as proteins, DNA, rodlike viruses, or actin filaments. Moreover, an understanding of the structural, dynamical and rheological properties of semiflexible polymers is of practical as well as of fundamental interest. In this context, we present our experiments on the successful shock wave destruction of tumor cells using laser-generated shock waves and then focus on a multiscale method, which couples the atomistic particle domain with the continuum domain. The new coupling method is based on Dissipative Particle Dynamics at constant Energy (DPDE) and Smooth Particle Hydrodynamics (SPH). It enables us to simulate realistically the interaction of shock waves with the membrane of cells and to investigate numerically the destructive effect of shock waves on these systems.

REFERENCES

[1] M. Schmidt, U. Kahlert, J. Wessolleck, D. Maciaczyk, B. Merkt, J. Maciaczyk, J. Osterholz, G. Nikkah and M.O. Steinhauser, "Characterization of a setup to test the impact of high-amplitude pressure waves on living cells", *Sci. Rep.*, **4**, 3849 (2014).

[2] M.O. Steinhauser and M. Schmidt, "Destruction of cancer cells by laser-induced shock waves: recent developments in experimental treatments and multiscale computer simulations", *Soft Matter*, **10**, 4778-4788 (2014).